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Inspection Manual for Toxic Air Pollutant Emissions

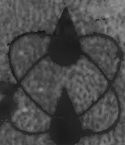
WAPORA, Inc, New York Northeastern Regional Office

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16. ABSTRACT This inspection manual provides guidelines for federal, state and local environmental agency enforcement personnel who need to arrive at preliminary assessments of potential toxic air pollution problems associated with chemical processing facilities and other emission sources for cases in which standards and regulations have not been promulgated. Included in the manual are discussions of inspection authority, emission toxicity, emission sources, control techniques, unsteady operations, emission data, field investigations and a variety of inspection forms. These forms pertain to equipment as reactors, dryers, grinders, mills, storage tanks, pumps, compressors, hoods, ductwork, industrial waste incinerators and emission control devices. The manual also includes correlations for the estimation of emissions, dispersion, and toxicity (from lethal dosages - LD50's), and compilations of threshold limit values (TLV's), other Occupational Safety and Health Administration (OSHA) standards, known and potential carcinogens, odor descriptions and thresholds, vapor pressures, required air velocities for pollutant capture, safety and inspection equipment, toxic emission preliminary assessment procedures, and principal toxic emission references.		
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August 1977

INSPECTION MANUAL
FOR
TOXIC AIR POLLUTANT
EMISSIONS

by:

Robert M. Cutler, Robert N. Rickles,
James A. Rogers and Thomas L. Sieger
WAPORA, Inc., Northeastern Regional Office
211 East 43rd Street, New York, NY 10017

Contract No. 68-02-2555

Project Officer
Abraham Ferdas
USEPA Region III
Sixth and Walnut Streets
Philadelphia, PA 19106

Prepared for:

U.S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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TABLE OF CONTENTS

<u>Chapter</u>		<u>Page</u>
-	Acknowledgments	iii
-	List of Exhibits	vi
1	Introduction	1-1
2	Authority to Inspect	2-1
3	Toxicity of Substances	3-1
4	Emission Sources	4-1
5	Control Techniques	5-1
6	Start-ups, Malfunctions and Shut-downs	6-1
7	Instrumentation, Monitoring, Record-keeping and Reporting	7-1
8	Field Investigations	8-1
-	References	ix

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LIST OF EXHIBITS

<u>Exhibit</u>		<u>Page</u>
2-1	Selected Sections of the Clean Air Act	2-3
3-1	Threshold Limit Values Adopted by the Occupational Safety and Health Administration	3-7
3-2	Additional Toxic and Hazardous Substances Regulated by the Occupational Safety and Health Administration	3-14
3-3	Relationships of Threshold Limit Values to Selected Ambient Air Quality Standards	3-15
3-4	Correlation Between Threshold Limit Values and Lethal-Dose 50's	3-16
3-5	Known and Potential Carcinogens As Listed by the Maryland Bureau of Air Quality	3-17
3-6	Odor Descriptions and Thresholds for Various Materials	3-18
4-1	Vapor Pressures of Organic Materials	4-9
4-2	Vapor Pressures of Inorganic Materials	4-22
4-3	Method for Estimating Storage Tank Emissions	4-25
5-1	Air Velocities Required at Locations of Contaminant Releases	5-6
8-1	Items of Safety and Inspection Equipment	8-22
8-2	Pre-Entry Chemical Emission Source Inspection Form	8-23

<u>Exhibit</u>		<u>Page</u>
8-3	Reactor Inspection Form	8-24
8-4	Dryer Inspection Form	8-25
8-5	Grinding or Milling Operation Inspection Form	8-26
8-6	Storage Tank Inspection Form	8-27
8-7	Pump and Compressor Inspection Form	8-28
8-8	Hood and Ductwork Inspection Form	8-29
8-9	Industrial Waste Incinerator Inspection Form	8-30
8-10	Emission Control Equipment Inspection Form	8-31
8-11	Chemical Substance Emission Source Summary Form	8-32
8-12	Toxic Emission Preliminary Assessment Procedure	8-33
8-13	Principal Reference Documents Recommended for Use by Toxic Air Pollutant Emission Investigators	8-34

CHAPTER 1

INTRODUCTION

This Inspection Manual for Toxic Air Pollutant Emissions has been prepared in order to aid air pollution control agency surveillance personnel in their inspections of facilities that manufacture or process certain chemical substances that may be released into the atmosphere and subsequently threaten human health or other aspects of the environment. Since it is recognized that most air pollution inspectors are neither degreed chemical engineers nor experienced in the chemical process industries, this manual presupposes only a knowledge of air pollution fundamentals and elementary principles of chemistry on the part of the user. Nevertheless, it is hoped and intended that the information presented in this document will also prove to be useful to many of the more experienced control agency personnel who must deal with toxic substance problems.

In the absence of directly applicable source facility emission regulations (except in the cases of those few industries regulated by the National Emission Standards for Hazardous Air Pollutants, or by similarly-designed state standards - cases considered to be outside the scope of this manual), the inspector's job as related to toxic substances can be an extremely difficult one. Although the Clean Air Act and State Implementation Plan air pollution prohibitions apply to all air contaminants adversely affecting human health or welfare, demonstrating that observed effects are attributable to a specific emission source is a task that cannot ordinarily be accomplished by an inspector alone, and more often cannot be accomplished at all.

The Toxic Substances Control Act (Public Law 94-469) may provide some degree of relief from such difficulties through the provisions of Section 6, "Regulation of Hazardous Chemical Substances

and Mixtures," which allows the EPA to propose and adopt rules to prevent any "unreasonable risk of injury to health or the environment"; Section 7, "Imminent Hazards," which allows the EPA to immediately commence court action to prevent any "imminent and unreasonable risk of serious or widespread injury"; and other sections. It is conceivable that field inspectors may become involved in the implementation of this act, but this matter is beyond the scope of this manual.

Because of the great significance of the general lack of toxic substance emission standards to the field investigator, the first post-introductory chapter of this manual is devoted to a discussion of his authority to conduct toxic substance emission inspections, and of the limits that have been placed upon that authority.

While the purpose of preparing this document was not to develop a definition of toxicity, which could be a very complex task indeed, it was nevertheless necessary to describe what is meant by the term toxic substance as used in this manual. A chapter has also been devoted to this important point.

The subjects of the remaining chapters are emission sources; control techniques; start-ups, malfunctions and shut-downs; instrumentation, monitoring, record-keeping and reporting; and, most important, field investigations, including discussions of the inspection procedures to be employed and the forms to be completed.

CHAPTER 2

AUTHORITY TO INSPECT

The primary source of authority for conducting facility inspections is set forth in the Clean Air Act under Section 114, entitled "Inspection, Monitoring, and Entry." Although there are (with few exceptions) no specific toxic substance implementation plan provisions, standards of performance, or emission standards with which compliance may need to be determined, Section 114 also authorizes inspections for the purposes of "developing or assisting in the development of" such plans and standards, and carrying out Section 303, "Emergency Powers."

Since the effectiveness of an emission regulation is ordinarily highly dependent on its enforceability through a field surveillance program, the need for conducting inspections as regulations are developed is apparent; however, in order to insure that the field inspection experience gained is actually utilized in the development of regulations, those responsible for such activities should be kept informed of inspection plans and programs, requested to provide comments and suggestions, and provided with copies of inspection reports. In this way, the need to duplicate inspection visits will be avoided, and regulations will not need to be drafted, proposed or promulgated without the benefit of sufficient field experience to insure their enforceability simply because of the lack of time to initiate a trial inspection program, or the lack of knowledge that an inspection program has been on-going.

The justification for inspections needed to carry out the provisions of Section 303 of the Clean Air Act should require no elaboration here. Similarly, the penalties provided under Section 113, "Federal Enforcement," that are applicable to cases in which field investigators are refused

access (see paragraph 113(b)(4)) need not be dwelled upon. The sections of the Clean Air Act discussed above are presented as Exhibit 2-1.

"FEDERAL ENFORCEMENT
SELECTED SECTIONS OF THE CLEAN AIR ACT"

"SEC. 113. (a) (1) Whenever, on the basis of any information available to him, the Administrator finds that any person is in violation of any requirement of an applicable implementation plan, the Administrator shall notify the person in violation of the plan and the State in which the plan applies of such finding. If such violation extends beyond the 30th day after the date of the Administrator's notification, the Administrator may issue an order requiring such person to comply with the requirements of such plan or he may bring a civil action in accordance with subsection (b)."

"(2) Whenever, on the basis of information available to him, the Administrator finds that violations of an applicable implementation plan are so widespread that such violations appear to result from a failure of the State in which the plan applies to enforce the plan effectively, he shall so notify the State. If the Administrator finds such failure extends beyond the thirtieth day after such notice, he shall give public notice of such finding. During the period beginning with such public notice and ending when such State satisfies the Administrator that it will enforce such plan (hereafter referred to in this section as 'period of Federally assumed enforcement'), the Administrator may enforce any requirement of such plan with respect to any person—

"(A) by issuing an order to comply with such requirement, or

"(B) by bringing a civil action under subsection (b)."

"(3) Whenever, on the basis of any information available to him, the Administrator finds that any person is in violation of section 111(e) (relating to new source performance standards) or 112(c) (relating to standards for hazardous emissions), or is in violation of any requirement of section 114 (relating to inspections, etc.), he may issue an order requiring such person to comply with such section or requirement, or he may bring a civil action in accordance with subsection (b)."

"(4) An order issued under this subsection (other than an order relating to a violation of section 112) shall not take effect until the person to whom it is issued has had an opportunity to confer with the Administrator concerning the alleged violation. A copy of any order issued under this subsection shall be sent to the State air pollution control agency of any State in which the violation occurs. Any order issued under this subsection shall state with reasonable specificity the nature of the violation, specify a time for compliance which the Administrator determines is reasonable, taking into account the seriousness of the violation and any good faith efforts to comply with applicable requirements. In

any case in which an order under this subsection (or notice to a violator under paragraph (1)) is issued to a corporation, a copy of such order (or notice) shall be issued to appropriate corporate officers.

"(b) The Administrator may commence a civil action for appropriate relief, including a permanent or temporary injunction, whenever any person—

"(1) violates or fails or refuses to comply with any order issued under subsection (a); or

"(2) violates any requirement of an applicable implementation plan during any period of Federally assumed enforcement more than 30 days after having been notified by the Administrator under subsection (a) (1) of a finding that such person is violating such requirement; or

"(3) violates section 111(e) or 112(c); or

"(4) fails or refuses to comply with any requirement of section 114.

Any action under this subsection may be brought in the district court of the United States for the district in which the defendant is located or resides or is doing business, and such court shall have jurisdiction to restrain such violation and to require compliance. Notice of the commencement of such action shall be given to the appropriate State air pollution control agency.

"(c) (1) Any person who knowingly—

"(A) violates any requirement of an applicable implementation plan during any period of Federally assumed enforcement more than 30 days after having been notified by the Administrator under subsection (a) (1) that such person is violating such requirement, or

"(B) violates or fails or refuses to comply with any order issued by the Administrator under subsection (a), or

"(C) violates section 111(e) or section 112(c)

shall be punished by a fine of not more than \$25,000 per day of violation, or by imprisonment for not more than one year, or by both. If the conviction is for a violation committed after the first conviction of such person under this paragraph, punishment shall be by a fine of not more than \$50,000 per day of violation, or by imprisonment for not more than two years, or by both.

"(2) Any person who knowingly makes any false statement, representation, or certification in any application, record, report, plan, or other document filed or required to be maintained under this Act or who falsifies, tampers with, or knowingly renders inaccurate any monitoring device or method required to be maintained under this Act, shall upon conviction, be punished by a fine of not more than \$10,000, or by imprisonment for not more than six months, or by both.

"INSPECTIONS, MONITORING, AND ENTRY

"SEC. 114. (a) For the purpose (i) of developing or assisting in the development of any implementation plan under section 110 or 111(d), any standard of performance under section 111, or any emission standard under section 112(ii) of determining whether any person is in violation of any such standard or any requirement of such a plan, or (iii) carrying out section 303—

"(1) the Administrator may require the owner or operator of any emission source to (A) establish and maintain such records, (B) make such reports, (C) install, use, and maintain such monitoring equipment or methods, (D) sample such emissions (in accordance with such methods, at such locations, at such intervals, and in such manner as the Administrator shall prescribe), and (E) provide such other information, as he may reasonably require; and

"(2) the Administrator of his authorized representative, upon presentation of his credentials—

"(A) shall have a right of entry to, upon, or through any premises in which an emission source is located or in which any records required to be maintained under paragraph (1) of this section are located, and

"(B) may at reasonable times have access to and copy any records, inspect any monitoring equipment or method required under paragraph (1), and sample any emissions which the owner or operator of such source is required to sample under paragraph (1).

"(b) (1) Each State may develop and submit to the Administrator a procedure for carrying out this section in such State. If the Administrator finds the State procedure is adequate, he may delegate to such State any authority he has to carry out this section (except with respect to new sources owned or operated by the United States).

"(2) Nothing in this subsection shall prohibit the Administrator from carrying out this section in a State.

"(c) Any records, reports or information obtained under subsection (a) shall be available to the public, except that upon a showing satisfactory to the Administrator by any person that records, reports, or information, or particular part thereof, (other than emission data) to which the Administrator has access under this section if made public, would divulge methods or processes entitled to protection as trade secrets of such person, the Administrator shall consider such record, report, or information or particular portion thereof confidential in accordance with the purposes of section 1905 of title 18 of the United States Code, except that such record, report, or information may be disclosed to other officers, employees, or authorized representatives of the United States concerned with carrying out this Act or when relevant in any proceeding under this Act.

"EMERGENCY POWERS

"SEC. 303. Notwithstanding any other provisions of this Act, the Administrator upon receipt of evidence that a pollution source or combination of sources (including moving sources) is presenting an imminent and substantial endangerment to the health of persons, and that appropriate State or local authorities have not acted to abate such sources, may bring suit on behalf of the United States in the appropriate United States district court to immediately restrain any person causing or contributing to the alleged pollution to stop the emission of air pollutants causing or contributing to such pollution or to take such other action as may be necessary.

CHAPTER 3

TOXICITY OF SUBSTANCES

As mentioned in the introductory chapter of this manual, it is not intended to give a general definition of toxicity here; rather, what is meant by the term as used throughout this document will be explained.

Although virtually any material may be considered to be toxic if it is sufficiently concentrated and pervasive, in common air pollution terminology only those gases that are potentially harmful when inhaled at concentration levels of below perhaps 10 parts per million (ppm) by volume in air, or 0.001 percent, are generally regarded as being of significant toxicity. Even so, the description of a material as toxic usually carries the connotation that harmful effects may result from concentrations well below those that are acceptable for the major air pollutants (which include gases such as carbon monoxide, nitrogen dioxide, and sulfur dioxide), for which the National Ambient Air Quality Standards range down to 0.05 ppm. Regarding particulate substances, which are not present in the air as separate molecules and are thus not reported on a parts-per-million basis, a material would not usually be described as toxic if it were not potentially harmful at concentrations well below the 75 ug/m^3 total suspended particulate matter ambient standard.

While Threshold Limit Values (TLV's) and other such standards have been adopted by the Occupational Safety and Health Administration (OSHA) (1) for a significant number of substances (see Exhibits 3-1 and 3-2), comparisons of these occupational exposure guidelines with ambient air quality standards may often prove misleading, and result in a serious underestimation of a material's toxicity. This may be explained by the fact that the

ambient standards are designed to protect a much larger and more varied population (including the very young, the old, and the unusually sensitive) than are the TLV's. As a result, the occupational standards are typically about two orders of magnitude less restrictive than the most stringent (long-term) ambient standards. Some of these relationships are presented in Exhibit 3-3. If one keeps this difference (and its variability) in mind, the TLV compilation can serve as a useful guide to material toxicity in many cases.

One particularly serious shortcoming of relying on TLV's as toxicity indicators is that for the great preponderance of chemicals in use, even those for which toxicity studies have been performed, TLV's have neither been adopted nor proposed. The results of these studies are summarized in the National Institute of Occupational Safety and Health (NIOSH) publication entitled "Toxic Substances List" (2). Unfortunately, the data presented in it (e.g., lethal doses in milligrams per kilogram of body weight for various species of animals) would probably not prove to be very useful to most toxic substance field investigators directly.

Another book, authored by N. Irving Sax and entitled "Dangerous Properties of Industrial Materials" (3), is about as extensive as the NIOSH publication but includes toxicity ratings on a scale of 3 units, with the maximum rating of 3 indicating severe toxicity. Ratings are assigned for both acute and chronic effects, and for different modes of exposure (e.g., inhalation).

For the purposes of a toxic substances air pollution field investigator, the chemical substance could be looked up in the Sax book's alphabetically-ordered listing (which includes cross-referencing in cases of multiple chemical names) and the toxicity rating listed for chronic inhalation exposures could be noted. The reason for the selection of a chronic exposure rating is that this would

almost invariably be the type of effect for which an inspector would be looking. The inhalation mode of exposure is obviously that type which is most closely related to possible air pollution effects. The material in question could be considered to be toxic (as described above) if the rating were a 3; lower ratings could be considered to indicate that the material is not particularly toxic. Such a functional definition of toxicity would of course be imperfect, but would typically be found to approximate the common conception of air pollutant toxicity reasonably well, and to more often be on the conservative side.

For chemical substances for which the letter "U" (for "unknown") is given instead of a numerical toxicity rating, or for which no space for a rating has even been provided, there is frequently a comment, reference to related chemical listings, or other information that may enable the toxicity of the material in question to be estimated. Occasionally, a chemical substance may be found to be unlisted. In such cases, the toxicity ratings of several other closely-related chemicals may be checked. (If the chemical structure or any other relevant property of the unlisted chemical is not known to the field investigator, he may first consult the Chemical Rubber Company (CRC) "Handbook of Chemistry and Physics" (4) listings of either organic or inorganic materials, as may be appropriate.) Both the NIOSH and Sax books mentioned above are also useful in that they catalog and cross-reference materials by their trade names as well as by their chemical names.

The development of a means to quantify potentially toxic levels is described in the document "Estimation of Permissible Concentrations of Pollutants for Continuous Exposure" (5). This document presents the intentionally conservative (on the average) relationships:

$$x_p = 1.65 \times 10^{-3} \text{ (TLV)}$$

and:

$$x_p = 4.77 \times 10^{-5} (LD_{50})$$

where:

x_p = maximum permissible long-term
(about monthly) average ambient
air concentration (mg/m³)

TLV = threshold limit value (mg/m³)

LD₅₀ = lethal dose for 50% of rats (or
else mice) when administered
orally (orl), or else by intra-
peritoneal (ipr), but not by intra-
muscular (ims), injections (mg/kg
of animal body weight)

The above formulae are based on the ambient air to working-place air exposure time ratio (168 hr/40 hr), the small child to adult respiratory volume per unit of body weight ratio (a factor of about 2), and the lower 95% confidence limit of a TLV-LD₅₀ correlation (see Exhibit 3-4). In addition, the above-mentioned document indicates that, for carcinogenic materials (which are believed to be characterized by an exposure-risk relationship having no threshold), an ambient concentration of 1 ng/m³ is the lowest of concern and may thus be considered to be permissible. (See Exhibit 3-5 for carcinogens listed as part of Maryland Bureau of Air Quality's progressive toxic emission control program.) The results of either ambient monitoring or dispersion modeling can be compared to the calculated maximum permissible ambient air concentration in order to aid in the assessment of a potential toxic air pollution problem.

In keeping with the generally recommended practice for determining whether occupational exposures to mixtures of air contaminants are consistent with TLV's, the consistency of ambient exposures to mixtures with maximum permissible concentrations can be assumed if:

$$\sum^n (x_i/x_{pi}) \leq 1$$

where:

$\sum^n$ = summation of terms for all n mixture components

x_i = actual concentration of mixture component i

x_{pi} = maximum permissible concentration of mixture component i

This approach is equivalent to the statement that:

$$x_{pm} = 1/\sum^n (f_i/x_{pi})$$

where:

x_{pm} = maximum permissible total mixture concentration

$\sum^n$ = summation of terms for all n mixture components

f_i = fraction of component i in mixture (mass fraction if concentrations are expressed in mass/volume units, volume fraction if concentrations are expressed in volume/volume units)

x_{pi} = maximum permissible concentration of mixture component i

When the toxicity of a material or mixture cannot be determined with a reasonable degree of certainty by methods such as those described above, it may be prudent for the field investigator to assume that the material or mixture in question is a toxic one.

It is worth noting at this point that, while

many materials are potentially toxic at concentrations so low as to be below the sensitivity of most commonly used measurement techniques, many materials are also odorous at extremely low concentrations (6,7,8). In cases where a field investigator can smell a material whose odor threshold is known to be above the permissible concentration, a toxicity problem may well exist. Conversely, if an inspector cannot smell a material whose odor threshold is below the permissible level (assuming he is at a suitable downwind location), a toxicity problem may well not exist, though the difficulty of detecting odors in the outdoor air at laboratory-test thresholds must be taken into account. Because of the value of odor in assessing potential atmospheric contaminant toxicity problems, an extensive list of odor descriptions and thresholds is included as Exhibit 3-6. These data should only be utilized with an understanding of the great uncertainties inherent in measuring odors (see the large ranges listed for some substances).

EXHIBIT 3-1

THRESHOLD LIMIT VALUES ADOPTED BY THE OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

Subpart Z—Toxic and Hazardous Substances

Source: 39 FR 23502, June 27, 1974, unless otherwise noted. Redesignated at 40 FR 27073, May 28, 1975.

§ 1910.1000 Air contaminants.

An employee's exposure to any material listed in table Z-1, Z-2, or Z-3 of this section shall be limited in accordance with the requirements of the following paragraphs of this section.

(a) Table Z-1:

(1) *Materials with names preceded by "C"—Ceiling Values.* An employee's exposure to any material in table Z-1, the name of which is preceded by a "C" (e.g., C Boron trifluoride), shall at no time exceed the ceiling value given for that material in the table.

(2) *Other materials—8-hour time weighted averages.* An employee's exposure to any material in table Z-1, the name of which is not preceded by "C", in any 8-hour work shift of a 40-hour work week, shall not exceed the 8-hour time weighted average given for that material in the table.

(b) Table Z-2:

(1) *8-hour time weighted averages.* An employee's exposure to any material listed in table Z-2, in any 8-hour work shift of a 40-hour work week, shall not exceed the 8-hour time weighted average limit given for that material in the table.

(2) *Acceptable ceiling concentrations.* An employee's exposure to a material listed in table Z-2 shall not exceed at any time during an 8-hour shift the acceptable ceiling concentration limit given for the material in the table, except for a time period, and up to a concentration not exceeding the maximum duration and concentration allowed in the column under "acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift".

(3) *Example.* During an 8-hour work shift, an employee may be exposed to a concentration of Benzene above 25 p.p.m. (but never above 50 p.p.m.) only for a maximum period of 10 minutes. Such exposure must be compensated by exposures to concentrations less than 10 p.p.m. so that the cumulative exposure for the entire 8-hour work shift does not exceed a weighted average of 10 p.p.m.

(c) **Table Z-3:** An employee's exposure to any material listed in table Z-3, in any 8-hour work shift of a 40-hour

work week, shall not exceed the 8-hour time weighted average limit given for that material in the table.

(d) Computation formulas:

(1) (i) The cumulative exposure for an 8-hour work shift shall be computed as follows:

$$E = \frac{C_1 T_1 + C_2 T_2 + \dots + C_n T_n}{8}$$

Where:

E is the equivalent exposure for the working shift.

C is the concentration during any period of time T where the concentration remains constant.

T is the duration in hours of the exposure at the concentration C .

The value of E shall not exceed the 8-hour time weighted average limit in table Z-1, Z-2, or Z-3 for the material involved.

(ii) To illustrate the formula prescribed in subdivision (i) of this subparagraph, note that isoamyl acetate has an 8-hour time weighted average limit of 100 p.p.m. (table Z-1). Assume that an employee is subject to the following exposure:

Two hours exposure at 150 p.p.m.

Two hours exposure at 75 p.p.m.

Four hours exposure at 50 p.p.m.

Substituting this information in the formula, we have

$$\frac{2 \times 150 + 2 \times 75 + 4 \times 50}{8} = 81.25 \text{ p.p.m.}$$

Since 81.25 p.p.m. is less than 100 p.p.m., the 8-hour time weighted average limit, the exposure is acceptable.

(2) (i) In case of a mixture of air contaminants an employer shall compute the equivalent exposure as follows:

$$E = \frac{C_1}{L_1} + \frac{C_2}{L_2} + \dots + \frac{C_n}{L_n}$$

Where:

E is the equivalent exposure for the mixture.

C is the concentration of a particular contaminant.

L is the exposure limit for that contaminant, from table Z-1, Z-2, or Z-3.

The value of E shall not exceed unity (1).

(ii) To illustrate the formula prescribed in subdivision (i) of this subparagraph, consider the following exposures:

Material	Actual concentration of 8-hour exposure	8-hour time weighted average exposure limit
Acetone (Table Z-1).....	800 p.p.m.	1,000 p.p.m.
2-Butanone (Table Z-1)....	45 p.p.m.	200 p.p.m.
Toluene (Table Z-2).....	40 p.p.m.	200 p.p.m.

Substituting in the formula, we have:

$$E = \frac{800}{1,000} + \frac{45}{200} + \frac{40}{200}$$

$$E = 0.800 + 0.225 + 0.200$$

$$E = 0.925$$

Since E is less than unity (1), the exposure combination is within acceptable limits.

(c) To achieve compliance with paragraph (a) through (d) of this section, administrative or engineering controls must first be determined and implemented whenever feasible. When such controls are not feasible to achieve full compliance, protective equipment or any other protective measures shall be used to keep the exposure of employees to air contaminants within the limits prescribed in this section. Any equipment and/or technical measures used for this purpose must be approved for each particular use by a competent industrial hygienist or other technically qualified person. Whenever respirators are used, their use shall comply with § 1910.134.

TABLE Z-1

Substance	p.p.m.*	mg./M ³ *
Acetaldehyde.....	200	380
Acetic acid.....	10	25
Acetic anhydride.....	5	20
Acetone.....	1,000	2,400
Acetonitrile.....	40	70
Acetylene dichloride, see 1, 2-Dichloroethylene.....		
Acetylene tetrachloride.....	1	14
Acrolein.....	0.1	0.25
Acrylamide—Skin.....		0.2
Acrylonitrile—Skin.....	20	45
Aldrin—Skin.....		0.25
Allyl alcohol—Skin.....	2	5
Allyl chloride.....	1	3
“C” Allylisobutyl ether (AOE).....	10	45
Allyl propyl disulfide.....	2	12
2-Aminoethanol, see Ethanol-amine.....		
2-Aminopyridine.....	0.5	2
“Ammonia.....	80	25
Ammonium sulfate (Am-mate).....		15
n-Amyl acetate.....	100	225
sec-Amyl acetate.....	125	450
Aniline—Skin.....	5	19
Anilidine (o, p-isomers)—Skin.....		0.5
Antimony and compounds (as Sb).....		0.5

See footnotes at end of table.

TABLE Z-1—Continued

Substance	p.p.m.*	mg./M ¹ *
ANTU (alpha naphthyl thioarea).....		0.3
Arenic and compounds (see Aa).....		0.3
Arsine.....	0.05	0.2
Asinphos-methyl-Skin.....		0.2
Barium (soluble compounds).....		0.3
p-Benzquinone, see Quinone.....		
Benzoyl peroxide.....		5
Benzyl chloride.....	1	5
Biphenyl, see Diphenyl.....		
Bisphenol A, see Diglycidyl ether.....		
Boron oxide.....		15
C Boron trifluoride.....	1	3
Bromine.....	0.1	0.7
Bromoform-Skin.....	0.5	5
Butadiene (1,3-butadiene).....	1,000	2,300
Butanethiol, see Butyl mercaptan.....		
2-Butanone.....	300	800
2-Butoxy ethanol (Butyl Cellosolve)-Skin.....	50	240
Butyl acetate (n-butyl acetate).....	150	710
sec-Butyl acetate.....	300	950
tert-Butyl acetate.....	300	950
Butyl alcohol.....	100	300
sec-Butyl alcohol.....	150	450
tert-Butyl alcohol.....	100	300
C Butylamine-Skin.....	5	15
C tert-Butyl chromate (as CrO ₃)-Skin.....		0.1
n-Butyl glycidyl ether (BGE).....	50	370
*Butyl mercaptan.....	10	35
p-tert-Butyltoluene.....	10	60
Calcium arsenate.....		1
Calcium oxide.....		5
**Campher.....	2	
Carbaryl (Sevin ®).....		5
Carbon black.....		2.5
Carbon dioxide.....	5,000	9,000
Carbon monoxide.....	50	55
Chlordane-Skin.....		0.5
Chlorinated camphene-Skin.....		0.5
Chlorinated diphenyl oxide.....		0.5
Chlorine.....	1	3
Chlorine dioxide.....	0.1	0.3
C Chlorine trifluoride.....	0.1	0.4
C Chloroacetaldehyde.....	1	3
*Chloroacetophenone (phenacylchloride).....	0.05	0.3
Chlorobenzene (monochlorobenzene).....	75	350
*Chlorobenzyliden malononitrile (OCBM).....	0.05	0.4
Chlorobromomethane.....	200	1,070
2-Chloro-1,3-butadiene, see Chloroprene.....		
Chlorodiphenyl (42 percent Chlorine)-Skin.....		1
Chlorodiphenyl (54 percent Chlorine)-Skin.....		0.5
1-Chloro-2,3-epoxypropane, see Epichlorohydrin.....		
3-Chloroethanol, see Ethylene chlorohydrin.....		
Chloroethylene, see Vinyl chloride.....		
C Chloroform (trichloromethane).....	50	240
1-Chloro-1-nitropropane.....	20	100
Chloropieris.....	0.1	0.7
Chloroprene (2-chloro-1,3-butadiene)-Skin.....	25	90
Chromium, sol. chromic, chromous salts as Cr.....		0.5
Metal and insol. salts.....		1

See footnotes at end of table.

TABLE Z-1—Continued

Substance	p.p.m.*	mg./M ¹ *
Coal tar pitch volatiles (benzene soluble fraction) anthracene, BaP, phenanthrene, acridine, chrysene, pyrene.....		0.3
Cobalt, metal fume and dust.....		0.1
Copper fume.....		0.1
Dusts and Mists.....		1
Cotton dust (raw).....		15
Crag® herbicide.....		22
Cresol (all isomers)-Skin.....	2	5
Crotonaldehyde.....	50	345
Cumene-Skin.....	300	1,050
Cyanide (as CN)-Skin.....	50	200
Cyclohexane.....	50	200
Cyclohexanol.....	50	200
Cyclohexanone.....	300	1,015
Cyclohexene.....	75	200
Cyclopentadiene.....		10
2,4-D.....		1
DDT-Skin.....		0.05
DDVP, see Dichlorvos.....		
Decaherane-Skin.....	0.05	0.1
Demeton®-Skin.....		0.1
Diacetone alcohol (4-hydroxy-4-methyl-2-pentanone).....	50	340
1,2-diaminoethane, see Ethylenediamine.....		
Diazomethane.....	0.2	0.4
Diborane.....	0.1	0.1
Dibutylphthalate.....		5
C o-Dichlorobenzene.....	50	300
p-Dichlorobenzene.....	75	450
Dichlorodifluoromethane.....	1,000	4,550
1,2-Dichloro-3,5-dimethylhydantoin.....		0.2
1,1-Dichloroethane.....	100	400
1,2-Dichloroethylene.....	300	750
C Dichloroethyl ether-Skin.....	15	90
Dichloromethane, see Methylenechloride.....		
Dichloromonoisocyanomethane.....	1,000	4,500
C 1,1-Dichloro-1-nitroethane.....	10	60
1,2-Dichloropropane, see Propylenedichloride.....		
Dichlorotetrafluoroethane.....	1,000	2,000
Dichlorvos (DDVP)-Skin.....		1
Dieldrin-Skin.....		0.25
Diethylamine.....	25	75
Diethylamino ethanol-Skin.....	10	40
Diethylether, see Ethyl ether.....		
Difluorodibromomethane.....	100	500
C Diglycidyl ether (DGE).....	0.5	2.5
Dihydroxybenzene, see Hydroquinone.....		
Dibutyl ketone.....	50	250
Diisopropylamine-Skin.....	5	20
Dimethoxymethane, see Methylal.....		
Dimethyl acetamide-Skin.....	10	35
Dimethylamine.....	10	15
Dimethylaminobenzene, see Xylidene.....		
Dimethylaniline (N-dimethylaniline)-Skin.....	5	25
Dimethylbenzene, see Xylene.....		
Dimethyl 1,2-dibromo-2,5-dichloroethyl phosphate, (Dibrom).....		3
Dimethylformamide-Skin.....	10	30
2,6-Dimethylheptanone, see Diisobutyl ketone.....		
1,1-Dimethylhydrazine-Skin.....	0.5	1
Dimethylphthalate.....		5
Dimethylsulfate-Skin.....	1	5
Dinitrobenzene (all isomers)-Skin.....		1

See footnotes at end of table.

TABLE Z-1—Continued

Substance	p.p.m.*	mg./M ³ *
Dinitro-cresol—Skin.....		0.2
Dinitrotoluene—Skin.....		1.5
Dioxane (Dioxylene dioxide)—Skin.....	100	200
Diphenyl.....	0.2	1
Diphenylmethane diisocyanate (see Methylene bisphenyl isocyanate (MDI)).....		
Dipropylene glycol methyl ether—Skin.....	100	600
Di-sec-octyl phthalate (Di-2-ethylhexylphthalate).....		8
Endrin—Skin.....		0.1
Epichlorohydrin—Skin.....	5	10
EPN—Skin.....		0.5
1,2-Epoxypropane, see Propylene oxide.....		
2,3-Epoxy-1-propanol, see Glycidol.....		
Ethanesulfol, see Ethylmercaptan.....		
Ethanolamine.....	3	6
2-Ethoxyethanol—Skin.....	200	700
2-Ethoxyethylacetate (Cellulosolve acetate)—Skin.....	100	500
Ethyl acetate.....	400	1,400
Ethyl acrylate—Skin.....	25	100
Ethyl alcohol (ethanol).....	1,000	1,900
Ethylamine.....	10	18
Ethyl sec-amyl ketone (2-methyl-3-heptanone).....	25	130
Ethyl benzene.....	100	435
Ethyl bromide.....	200	800
Ethyl butyl ketone (3-Heptanone).....	50	250
Ethyl chloride.....	1,000	2,000
Ethyl ether.....	400	1,200
Ethyl formate.....	100	300
C Ethyl mercaptan.....	10	25
Ethyl silicate.....	100	850
Ethylene chlorohydrin—Skin.....	5	16
Ethylene diamine.....	10	25
Ethylene dibromide, see 1,2-Dibromoethane.....		
Ethylene dichloride, see 1,2-Dichloroethane.....		
C Ethylene glycol dinitrate and/or Nitroglycerin—Skin.....	0.2	1
Ethylene glycol isobutyryl ether acetate, see Methyl cellosolve acetate.....		
Ethylene imine—Skin.....	0.5	1
Ethylene oxide.....	50	50
Ethylidene chloride, see 1,1-Dichloroethane.....		
N-Ethylmorpholine—Skin.....	30	90
Perbenz.....		15
Ferrovanadium dust.....		1
Fluoride (as F).....		2.5
Fluorine.....	0.1	0.2
Fluorotrichloromethane.....	1,000	5,000
Formic acid.....	5	20
Furfural—Skin.....	50	200
Furfuryl alcohol.....	50	200
Glycidol (2,3-Epoxy-1-propanol).....	50	150
Glycol monoethyl ether, see 2-Ethoxyethanol.....		
Guthion @, see Azinphos-methyl.....		
Hahnum.....		0.5
Heptachlor—Skin.....		0.5
Heptane (n-heptane).....	800	2,000
Hexachloroethane—Skin.....	1	10
Hexachloronaphthalene—Skin.....		0.2
Hexane (n-hexane).....	500	1,800
2-Hexanone.....	100	410
Hexone (Methyl isobutyl ketone).....	100	410
sec-Hexyl acetate.....	50	300

See footnote at end of table.

TABLE Z-1—Continued

Substance	p.p.m.*	mg./M ³ *
Hydrazine—Skin.....	1	1.3
Hydrogen bromide.....	5	10
C Hydrogen chloride.....	5	7
Hydrogen cyanide—Skin.....	10	11
Hydrogen peroxide (50%).....	1	1.4
Hydrogen sulfide.....	0.05	0.2
Hydroquinone.....		2
C Iodine.....	0.1	1
Iron oxide fume.....		10
Isocetyl acetate.....	100	825
Isocetyl alcohol.....	100	300
Isobutyl acetate.....	130	700
Isobutyl alcohol.....	100	300
Isophorone.....	25	140
Isopropyl acetate.....	250	950
Isopropyl alcohol.....	400	550
Isopropylamine.....	5	12
Isopropyl ether.....	300	2,100
Isopropyl glycidyl ether (IGM).....	50	240
Ketane.....	0.5	0.9
Lead arsenate.....		0.15
Lindane—Skin.....		0.5
Lithium hydride.....		0.025
L.P.G. (liquid petroleum gas).....	1,000	1,900
Magnesium oxide fume.....		15
Malethion—Skin.....		15
Maleic anhydride.....	0.25	1
C Manganese.....	25	100
Methyl oxide.....		
Methanethiol, see Methyl mercaptan.....		
Methoxychlor.....		15
2-Methoxyethanol, see Methyl cellosolve.....		
Methyl acetate.....	200	110
Methyl acetylene (propyne).....	1,000	1,150
Methyl acetylene-propadiene mixture (MAFP).....	1,000	1,100
Methyl acrylate—Skin.....	10	35
Methylal (dimethoxymethane).....	1,000	3,100
Methyl alcohol (methanol).....	200	390
Methylamine.....	10	12
Methyl amyl alcohol, see Methyl isobutyl carbinol.....		
Methyl (n-amyl) ketone (2-Heptanone).....	100	445
C Methyl bromide—Skin.....	30	80
Methyl butyl ketone, see 2-Hexanone.....		
Methyl cellosolve—Skin.....	25	80
Methyl cellosolve acetate—Skin.....	25	120
Methyl chloroform.....	350	1,000
Methylcyclohexane.....	500	2,000
Methylcyclohexanol.....	100	470
o-Methylcyclohexanone—Skin.....	100	460
Methyl ethyl ketone (MEK), see 2-Butanone.....		
Methyl formate.....	100	250
Methyl iodide—Skin.....	5	25
Methyl isobutyl carbinol—Skin.....	25	100
Methyl isobutyl ketone, see 2-Hexanone.....		
Methyl isocyanate—Skin.....	0.02	0.05
C Methyl mercaptan.....	10	30
Methyl methacrylate.....	100	410
Methyl propyl ketone, see 2-Pentanone.....		
C α Methyl styrene.....	100	450
C Methylene bisphenyl isocyanate (MDI).....	0.02	0.2
Molybdenum.....		5
Insoluble compounds.....		15
Monomethyl aniline—Skin.....	5	9
C Monomethyl hydrazine—Skin.....	0.2	0.35
Morpholine—Skin.....	20	70
Naphtha (coal tar).....	100	400
Naphthalene.....	10	50

See footnotes at end of table.

TABLE Z-1—Continued

Substance	p.p.m. ^a	mg./M ^b
Nickel carbonyl.....	0.001	0.007
Nickel, metal and soluble compds., as Ni.....	1	8
Nicotine—Skin.....	0.5	0.5
Nitric acid.....	2	5
Nitric oxide.....	25	30
p-Nitroaniline—Skin.....	1	6
Nitrobenzene—Skin.....	1	5
p-Nitrochlorobenzene—Skin.....	1	1
Nitroethane.....	100	310
Nitrogen dioxide.....	5	9
Nitrogen trisulfide.....	10	29
Nitropropene—Skin.....	0.2	2
Nitrosobenzene.....	100	250
1-Nitropropane.....	25	90
2-Nitropropane.....	5	30
Nitrotoluene—Skin.....	1	1
Nitrotrichloromethane, see Chloroform.....		
Octachloronaphthalene—Skin.....	0.1	0.1
*Octane.....	800	2,350
*Oil mist, mineral.....	5	5
Osmium tetroxide.....	0.002	0.002
Oxalic acid.....	1	1
Oxygen difluoride.....	0.05	0.1
Ozone.....	0.1	0.2
Paraquat—Skin.....	0.5	0.5
Parathion—Skin.....	0.11	0.11
Pentachloro- <i>n</i> -butane—Skin.....	0.005	0.01
Pentachlorophenol—Skin.....	0.5	0.5
*Pentane.....	1,000	2,950
2-Pentanone.....	200	700
Perchloromethyl mercaptan.....	0.1	0.8
Perchloryl fluoride.....	3	13.8
Petroleum distillates (naphtha).....	800	2,000
Phenol—Skin.....	5	19
p-Phenylene diamine—Skin.....	1	0.1
Phenyl ether (vapor).....	1	7
Phenyl ether-biphenyl mixture (vapor).....	1	7
Phenylethylene, see Styrene.....		
Phenyl glycidyl ether (PGE).....	10	60
Phenylhydrazine—Skin.....	5	22
Phosgene (Mettaphos ®) Skin.....	0.1	0.1
Phosgene (carbonyl chloride).....	0.1	0.4
Phosphine.....	0.3	0.4
Phosphoric acid.....	1	1
Phosphorus (yellow).....	0.1	0.1
Phosphorus pentachloride.....	1	1
Phosphorus pentasulfide.....	1	1
Phosphorus trichloride.....	0.5	3
Phthalic anhydride.....	2	12
Picric acid—Skin.....	0.1	0.1
Pival ® (2-Pivalyl-1,3- indandione).....	0.1	0.1
Platinum (soluble salts) as Pt.....	0.002	0.002
Propargyl alcohol—Skin.....	1	1,800
Propane.....	1,000	1,800
n-Propyl acetate.....	200	840
Propyl alcohol.....	200	800
n-Propyl nitrate.....	25	110
Propylene dichloride.....	75	350
Propylene imine—Skin.....	2	5
Propylene oxide.....	100	240
Propylene, see Methylacetylene.....		
Pyrrhrium.....	5	5
Pyridine.....	5	15
Quinone.....	0.1	0.4
Quinone—Skin.....	1.5	1.5
Rhodium, metal fume and dusts, as Rh.....	0.1	0.1
Soluble salts.....	0.001	0.001
Ronnel.....	10	10
Ronnel (commercial).....	5	5
Selenium compounds (as Se).....	0.2	0.2
Selenium hexafluoride.....	0.05	0.4

See footnotes at end of table.

TABLE Z-1—Continued

Substance	p.p.m. ^a	mg./M ^b
Silver, metal and soluble com- pounds.....	0.01	0.01
Sodium fluorosulfate (100%) Skin.....	0.05	0.05
Sodium hydroxide.....	2	2
Stibine.....	0.1	0.5
*Stoddard solvent.....	800	2,050
Styrene.....	0.15	0.15
Sulfur dioxide.....	5	15
Sulfur hexafluoride.....	1,000	4,000
Sulfuric acid.....	1	1
Sulfur monochloride.....	1	6
Sulfur pentachloride.....	0.025	0.25
Sulfuryl fluoride.....	5	50
Systox, see Demeton ®.....		
24.57.....	10	10
Tantalum.....	5	5
TEBP—Skin.....	0.2	0.2
Tellurium.....	0.1	0.1
Tellurium hexafluoride.....	0.02	0.2
TEPP—Skin.....	0.05	0.05
*Terphenyls.....	1	9
1,1,2-Tetrachloro-2,2-difluoro- ethane.....	800	4,170
1,1,2,2-Tetrachloro-1,2-difluoro- ethane.....	800	4,170
1,1,2,2-Tetrachloroethane—Skin.....	5	35
Tetrachloroethylene, see Per- chloroethylene.....		
Tetrachloroethane, see Carbon tetrachloride.....		
Tetrachloronaphthalene—Skin.....	5	5
Tetramethyl lead (as Pb)—Skin.....	0.075	0.075
Tetrahydrofuran.....	200	800
Tetramethyl lead (as Pb)— Skin.....	0.07	0.07
Tetramethyl succinonitrile— Skin.....	0.5	5
Tetranitromethane.....	1	6
Tetrayl (2,4,6-trinitrophenyl- methyl)amine—Skin.....	1.5	1.5
Thallium (soluble com- pounds)—Skin as Tl.....	0.1	0.1
Thiam.....	5	5
Tin (inorganic compds., except oxides).....	5	5
Tin (organic compds.).....	0.1	0.1
C Toluene-2,4-dicyanate.....	0.02	0.14
o-Toluidine—Skin.....	5	22
Toxaphene, see Chlorinated camphene.....		
Tributyl phosphate.....	5	5
1,1,1-Trichloroethane, see Methyl chloroform.....		
1,1,2-Trichloroethane—Skin.....	10	45
Titaniumdioxide.....	15	15
Trichloromethane, see Chloro- form.....		
Trichlorosulfonate—Skin.....	5	5
1,2,2-Trichloropropane.....	80	300
1,1,2-Trichloro-1,2,2-trifluoro- ethane.....	1,000	7,000
Triethylamine.....	25	100
Trifluoromonomeromethane.....	1,000	4,100
2,4,6-Trinitrophenol, see Picric acid.....		
2,4,6-Trinitrophenylmethyl- nitramine, see Tetrayl.....		
Trinitrotoluene—Skin.....	1.5	1.5
Triorthocresyl phosphate.....	0.1	0.1
Triphenyl phosphate.....	5	5
Turpentine.....	100	800
Urethane (soluble compounds).....	0.05	0.05
Uranium (insoluble compounds).....	0.25	0.25
C Vanadium: V ₂ O ₅ dust.....	0.5	0.5
V ₂ O ₅ fume.....	0.1	0.1
Vinyl benzene, see Styrene.....		
Vinylcyanide, see Acrylonitrile.....		

See footnotes at end of table.

Chapter XVII—Occupational Safety and Health Admin.

\$ 1910.1000

TABLE Z-1—Continued

Substance	p.p.m. ^a	mg./M. ^b
Vinyl toluene	100	480
Warfarin	0.1	0.1
Xylene (xyol)	100	435
Xylidine—skin	5	25

^a1970 Addition.
^bParts of vapor or gas per million parts of contaminated air by volume at 25° C. and 760 mm. Hg pressure.
^cApproximate milligrams of particulate per cubic meter of air.
 (No footnote "c" is used to avoid confusion with ceiling value notations.)

TABLE Z-2—Continued

Substance	p.p.m. ^a	mg./M. ^b
Yttrium	1	1
Zinc chloride fume	1	1
Zinc oxide fume	5	5
Zirconium compounds (as Zr)	5	5

^aAn atmospheric concentration of not more than 0.02 p.p.m., or personal protection may be necessary to avoid headache.
^bAs sampled by method that does not collect vapor.
^cFor control of general room air, biologic monitoring is essential for personnel control.

TABLE Z-3

Material	8-hour time weighted average	Acceptable ceiling concentration	Acceptable maximum peak above the acceptable ceiling concentration for an 8-hour shift.	
			Concentration	Maximum duration
Benzene (Z37.4-1968)	10 p.p.m.	25 p.p.m.	50 p.p.m.	10 minutes.
Beryllium and beryllium compounds (Z37.25-1970)	2 µg./M. ^c	5 µg./M. ^c	25 µg./M. ^c	30 minutes.
Cadmium fume (Z37.5-1970)	0.1 mg./M. ^c	3 mg./M. ^c		
Cadmium dust (Z37.5-1970)	0.2 mg./M. ^c	0.5 mg./M. ^c		
Carbon disulfide (Z37.3-1968)	20 p.p.m.	30 p.p.m.	100 p.p.m.	Do.
Carbon tetrachloride (Z37.17-1967)	10 p.p.m.	25 p.p.m.	200 p.p.m.	5 minutes in any 4 hours.
Ethylene dibromide (Z37.31-1970)	20 p.p.m.	30 p.p.m.	50 p.p.m.	5 minutes.
Ethylene dichloride (Z37.31-1969)	80 p.p.m.	100 p.p.m.	200 p.p.m.	5 minutes in any 3 hours.
Formaldehyde (Z37.19-1967)	3 p.p.m.	5 p.p.m.	10 p.p.m.	30 minutes.
Hydrogen fluoride (Z37.23-1968)	do.	do.	do.	do.
Fluoride as dust (Z37.23-1969)	2.5 mg./M. ^c			
Lead and its inorganic compounds (Z37.11-1969)	0.3 mg./M. ^c			
Methyl chloride (Z37.15-1969)	100 p.p.m.	200 p.p.m.	300 p.p.m.	5 minutes in any 3 hours.
Methylene chloride (Z37.3-1969)	800 p.p.m.	1,000 p.p.m.	2,000 p.p.m.	5 minutes in any 2 hours.
Organic (alkyl) mercury (Z37.30-1969)	0.01 mg./M. ^c	0.04 mg./M. ^c		
Styrene (Z37.15-1969)	100 p.p.m.	200 p.p.m.	600 p.p.m.	5 minutes in any 3 hours.
Trichloroethylene (Z37.19-1967)	do.	do.	300 p.p.m.	5 minutes in any 2 hours.
Tetrachloroethylene (Z37.23-1967)	do.	do.	do.	5 minutes in any 3 hours.
Toluene (Z37.12-1967)	300 p.p.m.	300 p.p.m.	800 p.p.m.	10 minutes.
Hydrogen sulfide (Z37.3-1968)		20 p.p.m.	50 p.p.m.	10 minutes once only if no other measurable exposure occurs.
Mercury (Z37.8-1971)		1 mg./M. ^c		
Chromic acid and chromates (Z37.7-1971)		do.		

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§ 1910.1001

TABLE 2-3—MINERAL DUSTS

Substance	Mppcf*	Mg/M ³
Silica:		
Crystalline:		
Quartz (respirable).....	250 ¹	10mg/M ³ =
Quartz (total dust).....	%SiO ₂ +4	%SiO ₂ +2 10mg/M ³
Cristobalite: Use 1/2 the value calculated from the count or mass formulae for quartz.		%SiO ₂ +2
Tridymite: Use 1/2 the value calculated from the formulae for quartz.		
Amorphous, including natural diatomaceous earth.....	20	80mg/M ³ %SiO ₂
Silicates (less than 1% crystalline silica):		
Mica.....	20	
Soapstone.....	20	
Talc (non-asbestos-form)...	20 ²	
Talc (fibrous). Use asbestos limit.		
Tramadolite (see talc, fibrous)		
Portland cement.....	80	
Graphite (natural).....	15	
Coal dust (respirable fraction less than 8% SiO ₂).....		2.4mg/M ³ or 10mg/M ³
For more than 8% SiO ₂		%SiO ₂ +3
Inert or Nuisance Dust:		
Respirable fraction.....	15	8mg/M ³
Total dust.....	80	16mg/M ³

Note: Conversion factors—
mppcf×35.3=million particles per cubic meter
= particles per c.c.
* Millions of particles per cubic foot of air, based on impinger samples counted by light-field technique.
¹ The percentage of crystalline silica in the formula to the amount determined from air-borne samples, except in those instances in which other methods have been shown to be applicable.
² As determined by the membrane filter method at 430× phase contrast magnification.
= Both concentration and percent quartz for the application of this limit are to be determined from the fraction passing a size-selector with the following characteristics:
= Containing < 1% quartz; if > 1% quartz, use quartz limit.

Aerodynamic diameter (unit density sphere)	Percent passing selector
3	90
2.5	75
2.0	50
1.5	25
1.0	0

The measurements under this note refer to the use of an AEC instrument. If the respirable fraction of coal dust is determined with a MRE the figure corresponding to that of 2.4 Mg/M³ in the table for coal dust is 4.6 Mg/M³. [39 FR 23502, June 27, 1974. Redesignated and amended at 40 FR 23073, May 28, 1975]

EXHIBIT 3-2

ADDITIONAL TOXIC AND HAZARDOUS SUBSTANCES REGULATED BY THE
OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

<u>29 CFR Section</u>	<u>Material</u>
1910.1001	Asbestos (8-hr avg. 2 fibers/cm ³ , ceiling 10 fibers/cm ³)
1910.1002	Coal tar pitch volatiles (interpretation of term)
1910.1003	4-Nitrobiphenyl
1910.1004	alpha-Naphthylamine
1910.1005	4,4' Methylene bis (2-chloroaniline)
1910.1006	Methyl chloromethyl ether
1910.1007	3,3'-Dichlorobenzidine (and its salts)
1910.1008	bis-Chloromethyl ether
1910.1009	beta-Naphthylamine
1910.1010	Benzidine
1910.1011	4-Aminodiphenyl
1910.1012	Ethyleneimine
1910.1013	beta-Propiolactone
1910.1014	2-Acetylaminofluorene
1910.1015	4-Dimethylaminobenzene
1910.1016	N-Nitrosodimethylamine
1910.1017	Vinyl chloride (8-hr avg. 1 ppm, 15-min. avg. 5 ppm)

EXHIBIT 3-3

RELATIONSHIPS OF THRESHOLD LIMIT VALUES TO
SELECTED AMBIENT AIR QUALITY STANDARDS

<u>Pollutant</u>	<u>Most Stringent Ambient Standard</u>	<u>TLV</u>	<u>TLV/ Ambient Standard</u>
Beryllium	0.01 ug/m ³	2 ug/m ³	200
Mercury	1.0 ug/m ³	50 ug/m ³	50
Nitrogen dioxide	0.05 ppm	5 ppm	100
Sulfur dioxide	0.03 ppm	5 ppm	167
Geometric mean			114

EXHIBIT 3-4

CORRELATION BETWEEN THRESHOLD LIMIT VALUES AND LETHAL-DOSE 50'S

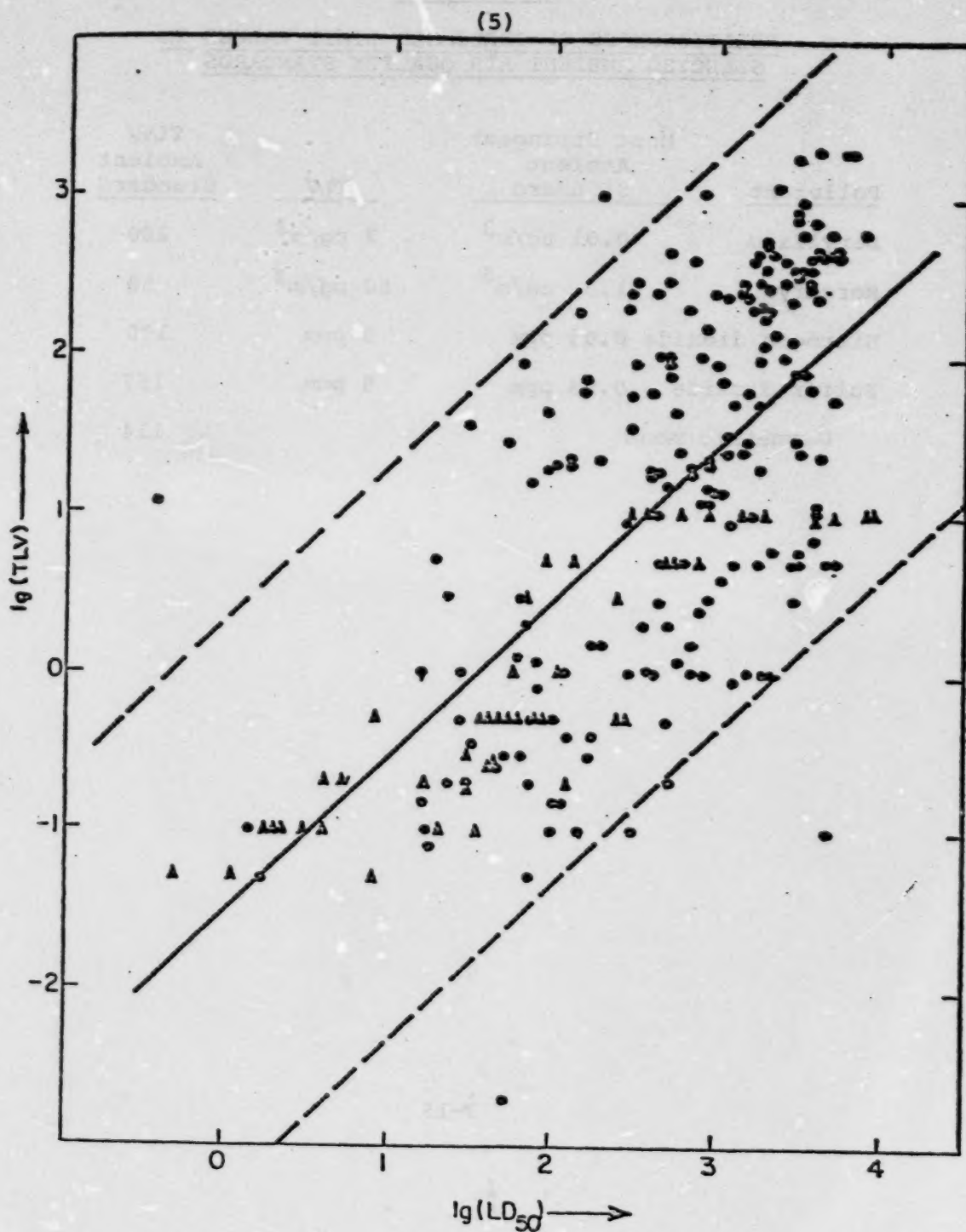


EXHIBIT 3-5

KNOWN AND POTENTIAL CARCINOGENS
AS LISTED BY THE MARYLAND BUREAU OF AIR QUALITY

Known Carcinogens

2-Acetylamino Fluorene
4-Aminodiphenyl
Arsenic
Arsenic Pentoxide
Arsenic Trioxide
Asbestos (all forms)
Auramine
Benzidine and its Salts
Beryl
Beryllium
Beryllium Oxide
Beryllium Sulfate
Calcium Arsenate
Calcium Arsenite (CaAsO_3H)
N,N,-bis(2 Chloroethyl) 2-Naphthylamine
bis-Chloromethyl Ether
3,3' - Dichlorobenzidine
4-Dimethylaminoazobenzene
Disodium Hydrogen Arsenate
Ethyleneimine
Methyl Chloromethyl Ether
alpha-Naphthylamine
beta-Naphthylamine
Nitrobiphenyl
Nitrosodimethylamine
Potassium Arsenate (KH_2AsO_4)
Potassium Arsenite
beta-Propiolactone
Sodium Arsenate
Sodium Arsenite (NaAsO_2)
Vinyl Chloride Monomer

Potential Carcinogens

Benzene
Benzo (a) Pyrene
Bertrandite
Beryllium Zinc Silicate
Cadmium Oxide
Chromite
Chromium Oxide
Coal Tar Pitch
Pyrenes
Anthracenes
Phenanthrenes
Acridines
Benzpyrenes
Chrysene
Dimethyl Sulfate
Hydrazine
Lead Chromate
4,4' - Methylene-bis-Chloroaniline
Nickel Carbonyl
Nickel Sulfide
Propane Sultone
Sodium Dichromate
Zinc Chromate

EXHIBIT 3-6

ODOR DESCRIPTIONS AND THRESHOLDS FOR VARIOUS MATERIALS

(6,7,8)		
<u>Material</u>	<u>Odor Description</u>	<u>Odor Threshold (ppm)</u>
Acetaldehyde	Green sweet, oxidized	0.21
Acetic acid	Sour	1.0
Acetic anhydride		0.36
Acetone	Chem. sweet, pungent	100.0-320.
Acetophenone		0.60
Acrolein	Burnt, sweet, pungent	0.21-15.
Acrylic acid		1.04
Acrylonitrile	Onion/garlic-pungency	21.4
Allyl chloride	Fishy	0.47
Allyl disulfide		0.0001
Allyl mercaptan		0.00005
Ammonia	Barn-like, pungent	0.037-46.8
Amyl acetate (primary, mixed isomers)		0.21
Amyl alcohol		1.0-10.
Aniline	Oily, solvent, pungent	1.0
Apiole		0.0063
Benzene	Solvent	4.68-60.
Benzyl chloride	Solvent	0.047
Benzyl sulfide	Cedary, sulfidy	0.0021
Bromine	Irritation, bleach	0.047
1,3-Butadiene		1.3
n-Butanol		2.0-11.
2-Butanol		0.56
n-Butyl acetate		7.
Butyl acetate (isomers unspecified)		0.037
n-Butyl amine		0.24
Butyl cellosolve		0.48
Butyl cellosolve acetate		0.20

<u>Material</u>	<u>Odor Description</u>	<u>Odor Threshold (ppm)</u>
n-Butyl chloride		16.7
Butylene oxide		0.71
n-Butyl ether		0.47
n-Butyl formate		17.
Butyraldehyde		0.039
Butyric acid	Sour	0.00028- 0.001
Camphor		16.
Carbitol acetate		0.263
Carbitol solvent		1.10
Carbon disulfide	Vegetable sulfide	0.21-7.7
Carbon tetrachloride (chlorination of CS ₂)	Sweet, pungent	21.4
Carbon tetrachloride (chlorination of CH ₄)		100.0
Carbon tetrachloride (source un- specified)		200.
Cellosolve acetate		0.250
Cellosolve solvent		1.3
Chloral	Sweet, fruity	0.047
Chlorine	Pungent, bleach	0.01-0.214
Chlorobenzene (mono- chlorobenzene)	Chlorinated, moth balls	0.21
p-Cresol	Tar-like, pungent	0.001
Cumene		0.047
Cyclohexanone		0.24
Diacetone alcohol		1.7
Diacetyl		0.025
Di-N-butyl amine		0.48
1,2-Dichloroethane		110.
Dicyclopentadiene		0.20
Diethyl amine		0.06
Diethyl ethanolamine		0.04
Diethyl ketone		9.
Diisobutyl carbinol		0.160
Diisobutyl ketone		0.31

<u>Material</u>	<u>Odor Description</u>	<u>Odor Threshold (ppm)</u>
Diisopropyl amine		0.85
Dimethyl acetamide	Amine, burnt, oily	46.8
Dimethyl amine	Fishy	0.047-6.
Dimethyl ethanol-amine		0.045
Dimethyl formamide	Fishy, floral, pungent	100.0
Dimethyl sulfide	Cooked vegetable	0.001-0.02
1-4, Dioxane		5.7
Dioxane (isomer(s) unspecified)		170.
1-3, Dioxolane		128.0
Diphenyl ether (per-fume grade)		0.1
Diphenyl sulfide		0.0047
Di-N-propyl amine		0.10
Ethanol (synthetic)	Sweet, floral	10.0
Ethanol (source unspecified)		50.
2-Ethoxy-3,4-dihydro-1,2-pyran		0.60
Ethyl acetate		13.2-50.
Ethyl acrylate	Hot plastic, earthy	0.00036-0.00047
Ethyl amine (70-72% in water)		0.83
2-Ethyl butanol		0.77
Ethylene		700.
Ethylene diamine		11.2
Ethylene dichloride		40.0
Ethylene glycol		25.
Ethylene oxide		500.
2-Ethyl hexanol		0.138
Ethyl hexyl acetate		0.21
2-Ethyl hexyl acrylate		0.18
Ethylidene norbornene		0.073
Ethyl mercaptan	Earthy, sulfidy	0.000016-0.001

<u>Material</u>	<u>Odor Description</u>	<u>Odor Threshold (ppm)</u>
N-Ethyl morpholine		0.25
Ethyl selenide		0.000062
Ethyl selenomer- captan		0.00000018
Ethyl sulfide		0.00025
Formaldehyde	Hay/straw-like, pungent	1.0
Glycol diacetate		0.321
Heptane		220.
1-Hexanol		0.09
Hydrogen chloride	Pungent, burnt	10.0
Hydrogen selenide		3.
Hydrogen sulfide (from Na ₂ S)	Boiled eggs	0.0047
Hydrogen sulfide (source unspeci- fied)		0.00047- 0.0011
Iodoform		0.00037
Ionone		0.000000059
Isobutanol		2.05-40.
Isobutyl acetate		0.50-4.
Isobutyl acrylate		0.012
Isobutyl cellosolve		0.191
Isobutyraldehyde		0.236
Isodecanol		0.042
Isopentanoic acid (mixed isomers)		0.026
Isophorone		0.54
Isopropanol		28.2-40.
Isopropyl acetate		0.97-30.
Isopropyl amine		0.95
Isopropyl ether		0.053
Mesityl oxide		0.051
Methanol	Sweet, fruity	53.3-5900.
Methyl acetate		200.
Methyl amine (monomethyl amine)	Fishy, pungent	0.021
Methyl amyl acetate		0.40
Methyl amyl alcohol		0.52

<u>Material</u>	<u>Odor Description</u>	<u>Odor Threshold (ppm)</u>
2-Methyl butanol		0.23
Methyl cellosolve		0.40
Methyl cellosolve acetate		0.64
Methyl chloride		10.
Methylene chloride		150.-214.
Methylene glycol		60.
Methyl ethanolamine		3.4
Methyl ethyl ketone	Sweet	6.0-25.
2-Methyl-5-ethyl pyridine		0.010
Methyl formate		2000.
Methyl isoamyl alcohol		0.20
Methyl isoamyl ketone		0.070
Methyl isobutyl ketone	Sweet, floral	0.28-8.
Methyl mercaptan	Sulfidy, pungent	0.0011- 0.0021
Methyl methacrylate	Pungent, sulfidy	0.21-0.34
2-Methyl pentaldehyde		0.136
2-Methyl-1-pentanol		0.082
Methyl propyl ketone		8.
α -Methyl styrene		0.156
Morpholine		0.14
Motor fuel		30.-800.
Nitrobenzene	Shoe polish, pun- gent	0.0047
Octane		150.
Ozone		0.1
2,4-Pentanedione		0.024
n-Pentanol		0.31
Perchloroethylene	Chlorinated	4.68
Phenol	Medicinal, sweet	0.047-3.
Phosgene	Hay-like	1.0
Phosphine	Oniony, mustard	0.021
2-Picoline		0.46
n-Propanol		0.13-30.
Propionaldehyde		0.80
Propionic acid		0.034

<u>Material</u>	<u>Odor Description</u>	<u>Odor Threshold (ppm)</u>
n-Propyl acetate		0.15-20.
Propylene		67.6
Propylene diamine		0.067
Propylene dichloride		0.60
Propylene oxide		35.0
Propyl mercaptan		0.000075
Pyridine	Burnt, pungent, diamine	0.012-0.021
Skatole		0.000000075
Styrene (inhibited)	Solventy, rubbery	0.1
Styrene (uninhibited)	Solventy, rubbery, plasticky	0.047
Styrene (type unspecified)		0.15
Styrene oxide		0.40
Sulfur dichloride	Sulfidy	0.001
Sulfur dioxide	Oppressive	0.47-30.
Tetrachloroethylene		50.
Tetraethyl o-silicate		7.2
Tetrahydrofuran		30.
Toluene (from coke)	Floral, pungent, solventy	4.68
Toluene (from petroleum)	Moth balls, rubbery	2.14
Toluene (source unspecified)		1.74-40.
Toluene diisocyanate	Medicated bandage, pungent	2.14
1,1,1-Trichloroethane		400.
Trichloroethylene	Solventy	2.14-250.
Trichloromonofluoromethane (Ucon-11)		209.0
Trichlorotrifluoroethane (Ucon-113 solvent)		135.0
Triethyl amine		0.28
Trimethyl amine	Fishy, pungent	0.00021-4

<u>Material</u>	<u>Odor Description</u>	<u>Odor Threshold (ppm)</u>
Trinitro-tert-Butyl xylene (synthetic musk)		0.00000042
Valeric acid		0.00062
Vanillin		0.000000032
Vinyl acetate		0.55
p-Xylene	Sweet, moth balls	0.47
Xylene (isomer(s) unspecified)		0.27-20.

CHAPTER 4

EMISSION SOURCES

Since all air pollutants can be divided into two categories, gases and particulates, one must consider two types of potential atmospheric emissions. Gaseous emissions normally result from the evaporation of liquid materials or, less frequently encountered, the sublimation (change to the gaseous state without first passing through the liquid state) of solid materials. The rate of evolution of such emissions is almost always highly dependent on the volatility of the material under consideration.

The vapor pressures of a large number of organic materials are presented as a function of temperature in Exhibit 4-1, and similar data for inorganic materials are presented in Exhibit 4-2 (9). In order to use these exhibits to determine a material's vapor pressure (in millimeters of mercury), the temperature of the material (in degrees Centigrade) must be located on the line on which the material's name appears. At the top of the column in which the temperature is listed, the vapor pressure is indicated. Interpolation and extrapolation may be employed as needed; for accurate results, the listed data should be used to plot a smooth vapor pressure-versus-temperature curve, from which the vapor pressure at any temperature can be read. For cases in which the chemical of concern is not listed in the vapor pressure tables, the vapor pressures of chemicals having similar molecular weights and structures should be checked. (As noted previously, molecular weights and structures can be determined by using either the organic or inorganic tables of chemical properties that can be found in the CRC "Handbook of Chemistry and Physics.")

For example, consider the case of benzyl chloride, a toxic substance that has a Threshold Limit Value (TLV) of 1 part per million (ppm), to be present at a temperature of 70 degrees Fahrenheit, which is equivalent to $(70-32)/1.8$, or 21.1 degrees Centigrade ($^{\circ}\text{C}$), and under normal atmospheric pressure (760 millimeters of mercury). The closest temperature to this on the line labeled benzyl chloride in Exhibit 4-1 is 22.0°C , which is located in the first vapor pressure column on the left, the column headed 1 millimeter of mercury (mm Hg). Since the actual temperature of 21.1°C is slightly below the listed temperature of 22.0°C , the actual vapor pressure is slightly less than 1 mm Hg. The equilibrium benzyl chloride concentration above the liquid phase would therefore be just under 1 mm Hg/760 mm Hg, 0.13 percent, or 1300 ppm.

Such a concentration would require efficient containment, emission control (for example, by activated carbon adsorption or thermal incineration - see the following chapter for details), or atmospheric dilution by a factor of well over three orders of magnitude before it could be safely inhaled for a significant period of time. Such degrees of dilution are in fact ordinarily obtained in cases of elevated release locations; however, it should also be recalled that ambient levels should typically be kept far below TLV concentrations. (The methods that can be used to evaluate a situation's potential for toxic air pollution problems are summarized in Exhibit 8-12).

Repeating the above calculation for a somewhat different case, in which the benzyl chloride is maintained under a pressure of 30 pounds per square inch gauge (psig), i.e., above the atmospheric pressure of about 14.7 psi, which is the same as $30 + 14.7$ or 44.7 pounds per square inch absolute (psia), or 3.04 atmospheres (atm), or 2310 mm Hg, the equilibrium pollutant concentration would be reduced to 1 mm Hg/2310 mm Hg, 0.043 percent, or 430 ppm. On the other hand, if the benzyl chloride

were to be kept under a 10 psi vacuum (below the atmospheric pressure of 14.7 psi), which is the same as 4.7 psia, 0.32 atmospheres, or 243 mm Hg, the equilibrium pollutant concentration would be increased to 1 mm Hg/243 mm Hg, 0.41 percent, or 4100 ppm.

The above example calculations should serve to provide the toxic substance air pollution inspector with an indication of how to estimate emitted concentrations. (When mixtures of chemicals are involved, somewhat more complex calculations may be required, based on various approximate relationships, such as Raoult's Law, that are described in detail in physical chemistry textbooks.)

One additional example will be presented to show how mass emission rates, rather than just emitted concentrations, may be estimated. Suppose a 1500-gallon, or 200-cubic foot, vessel at atmospheric pressure that is almost empty but is saturated with benzyl chloride vapor is to be refilled with the chemical within a ten-minute period. At the 0.13 percent equilibrium concentration calculated above, the vessel's benzyl chloride vapor of $200 \times 0.13\%$ or 0.26 cubic feet, or (from the ideal gas law) 0.085 pounds, will be displaced during the operation, at an average rate of $0.085/10$ or 0.0085 pounds per minute. (If this seems to be a low emission rate, one might consider that the dilution air that would be required to reduce 0.0085 pounds per minute of benzyl chloride to its 1 ppm TLV amounts to 26,000 cubic feet per minute.)

A final general point that should be made regarding evaporative emission estimations is that, depending on the process situation, it may often be more appropriate to assume that considerably less than the equilibrium pollutant concentrations may be present, especially when the time element is small and the degree of mixing is low. A method for estimating storage tank

evaporative emissions based on vapor pressure data is presented as Exhibit 4-3, which has been reproduced from EPA Publication Number AP-42, "Compilation of Air Pollutant Emission Factors" (10). For fixed-roof petrochemical storage tanks, conservatively assuming the number of turnovers (the ratio of annual throughput to tank capacity) to be no greater than 36 per year, the evaporative emission formulae can be reduced to the expression:

$$E = MP (0.0104 D^{1.73} H^{0.51} \Delta T^{0.50} F_p C + 0.000024 G)$$

where:

E = evaporative emission rate (lb/yr)

M = molecular weight of petrochemical (lb/mole)

P = true vapor pressure of petrochemical at bulk liquid storage temperature (psia)

D = diameter of storage tank (ft)

H = average vapor space height (typically half of storage tank height, and including a correction for concave roof volume) (ft)

ΔT = average daily ambient temperature change, maximum minus minimum (typically about 20°F)

F_p = paint factor, ranging from 1.00 for tanks whose roofs and shells are coated with white paint in good condition, to 1.58 for medium-gray painted tanks in poor condition (see Exhibit 4-3)

C = correction factor for tanks with diameters of less than 30 feet, approximately equal to $D/20 - D^4/1,600,000$ (see Exhibit 4-3)

G = annual throughput of petrochemical (gal/yr)

The first term enclosed within the parentheses is needed to calculate the standing storage (breathing) loss, while the second term is needed to calculate the working (filling and emptying) loss.

Other potential sources of evaporative emissions of toxic substances include such chemical process equipment as reactor vessels, distillation columns, pumps, and compressors. Pollutant release points include stacks, vents, ejectors, and leaking ducts and pipes, and such occurrences as overflows and spills must also be considered. In addition, wastewater streams and solid waste accumulations should not be overlooked as possible sources of toxic evaporative emissions to the atmosphere, and treatment processes may actually result in increased releases of certain chemicals into the air. Such processes may often include the incineration of liquid or solid industrial waste materials.

Particulate emissions are ordinarily the result of the small particles present in a finely-divided (granular or powdered) solid material becoming airborne, or sometimes of very small droplets being entrained in an air stream flowing through a quantity of liquid, or over a liquid surface, or simply past a point where liquid splashing, spraying, or atomization (as at a high-pressure nozzle) occurs. (In cases where particulates are created by the condensation, reaction, or other transformation of gaseous pollutants, evaporative or other gaseous emission formation mechanisms are usually responsible.)

Just as gaseous emissions are most often attributable to the volatility of substances, particulate emissions are usually related to the degree to which materials are present in finely-divided form. This is due to the fact that coarser particles are much less likely to become and remain airborne. For example, 100-micrometer (or 0.1 mm) diameter particles settle to the ground so quickly that they are usually transported beyond

plant boundaries in significant quantities only in cases involving high initial release elevations and/or high wind speeds. Intermediate-sized particles, which have diameters of about 10 micrometers (or 0.01 mm) and are extremely difficult to distinguish as individual particles with the naked eye, are much more readily transported by the air over considerable distances. Very small particles, which have diameters of about 1 micrometer (0.001 mm) and are very difficult to see even with the aid of an optical microscope because their sizes approximate the wave-length of light, behave in many respects like gaseous molecules and have no significant tendency to undergo gravitational settling.

The percentage of small particles (those with diameters of less than a specified value) present in a finely-divided material which have the potential to become airborne may be determined based on a knowledge of the particle size distribution of the material. In air pollution work, the distribution most often encountered is the log-normal type, within which the logarithm of the particle diameter is distributed normally (according to the error function, or the standard bell curve) with respect to the mass of particles. For example, if one considers a granular material having a log-normal size distribution that is characterized by a mass median diameter of 100 micrometers and a geometric standard deviation of 2.5, it is known by definition that 68 percent of the mass of particles is between $100/2.5$ and 100×2.5 , or 40 micrometers and 250 micrometers, in diameter, while 16 percent of the mass is below 40 micrometers in diameter and the remaining 16 percent is above 250 micrometers in diameter. Through the utilization of graphical techniques or tabular data, the percentage of the mass of a finely-divided material below any size (chosen because of its likelihood of becoming airborne and being transported to the plant boundary or to a potentially sensitive or adversely affected receptor location) can be readily determined;

however, all of the particles below such a size may not actually be emitted, and in most cases only a small fraction of them will be released, depending on the degree to which the finely-divided material is exposed to the air, especially air in motion.

For some types of operations in which particulate emissions may be generated, emission rates may be estimated based on the data presented in EPA Publication Number AP-42, "Compilation of Air Pollutant Emission Factors." In cases where the source operation involved is not listed in AP-42, emission factors for similar operations may be considered for use, keeping in mind that the size distributions of the finely-divided process materials involved and their degrees of exposure to the air and its motion should be comparable. In the case of a solid material, its degree of dryness, dampness or stickiness may be highly significant. Since toxic substances may constitute only a fraction of the total emitted particulate matter, the composition of the finely-divided process material should be taken into account, including any systematic difference between the total and the toxic particle size distributions that may exist. Operations that may result in toxic substance particulate emissions include atomizing, blending, charging, conveying, crushing, cutting, drilling, mixing, packing, pulverizing, spraying, and others.

In the estimation of emission rates of potentially toxic materials, it may often be necessary to consider the differences in the weights of alternative chemical forms. For example, consider a process in which 4 pounds per day of vanadium (atomic symbol V, atomic weight 51) is converted to vanadium pentoxide fumes (molecular formula V_2O_5 , molecular weight $51 \times 2 + 16 \times 5$, or 182) and subsequently released to the atmosphere. Since the V_2O_5 has a mass of $182/(51 \times 2)$, or 1.75, times the mass of the vanadium it contains, the

emission rate of V_2O_5 would be 4×1.75 , or 7, pounds per day. Ambient concentrations calculated from this emission rate could then be compared directly to the V_2O_5 fume TLV of 50 ug/m^3 . It should be noted that in the cases of many toxic chemicals no such calculations would be required; for example, for the oxidation and emission of selenium, the increase in weight need not be calculated for the purpose of an ambient concentration evaluation, since the TLV for selenium compounds is 200 ug/m^3 expressed as the weight of selenium only (not including the weight of oxygen or other atoms compounded with the selenium).

This concludes the chapter on the types of toxic substance emissions that can be expected from the various sources, and on how these emissions may be estimated.

EXHIBIT 4-1

VAPOR PRESSURES OF ORGANIC MATERIALS (9)

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Compound		Pressure, mm. Hg										Mol. wt.
Name	Formula	1	5	10	20	40	60	100	200	400	760	
		Temperature, °C.										
Acetophenone	C ₈ H ₈ O	114.8	131.2	148.7	168.2	181.2	197.5	222.1	258.0	277.5	95	
Acetaldehyde	C ₂ H ₄ O	-23.0	-2.3	+8.0	19.4	31.9	46.8	64.3	84.0	102.2	44	
Acetic acid	C ₂ H ₄ O ₂	-81.5	-65.1	-54.8	-47.8	-39.4	-22.4	-10.0	+4.9	+22.5	122.5	
Acetonitrile	C ₂ H ₃ N	65.0	92.0	105.0	120.0	135.8	150.0	173.3	200.0	222.0	81	
Acetamide	C ₂ H ₅ NO	115.0	146.6	162.0	180.0	199.4	219.8	247.0	283.0	313.5	113.5	
Acetic anhydride	C ₄ H ₆ O ₃	-17.2	+4.3	17.5	29.9	43.0	57.7	73.0	99.0	118.1	16.7	
Acetone	C ₃ H ₆ O	1.7	24.8	36.0	48.3	62.1	76.0	92.0	119.8	139.4	-75	
Acetonitrile	C ₂ H ₃ N	-59.4	-40.5	-31.1	-20.8	-9.4	-2.0	+7.7	22.7	39.5	-94.6	
Acetone	C ₃ H ₆ O	-47.0	-26.4	-16.3	-5.0	+7.7	15.9	27.0	43.7	62.5	81.0	
Acetyl chloride	C ₂ H ₃ ClO	37.1	64.0	78.0	92.4	109.4	119.0	133.6	154.2	178.0	20.5	
Acetylene	C ₂ H ₂	-50.0	-35.0	-27.6	-19.6	-10.4	-4.5	+3.2	16.1	32.0	-112.0	
Acetic acid	C ₂ H ₄ O ₂	-142.9	-133.0	-128.2	-122.5	-116.7	-112.0	-107.9	-100.3	-92.0	-81.5	
Acetic anhydride	C ₄ H ₆ O ₃	-129.4	-105.8	-96.0	-86.3	-76.5	-66.8	-57.1	-47.4	-37.7	-110.5	
Acetic acid	C ₂ H ₄ O ₂	-44.5	-26.0	-16.3	-5.0	+7.7	15.9	27.0	43.7	62.5	-87.7	
Acetic acid	C ₂ H ₄ O ₂	+3.5	27.3	39.0	53.0	68.0	84.0	101.0	120.0	141.0	14	
Adipic acid	C ₆ H ₈ O ₄	159.5	191.0	205.5	222.0	240.5	251.0	265.0	287.5	312.5	152	
Allene (propadiene)	C ₃ H ₂	-120.6	-108.0	-101.0	-93.4	-85.2	-76.8	-67.5	-57.5	-47.0	-136	
Allyl alcohol (propen-1-ol-3)	C ₃ H ₆ O	-20.0	+0.2	10.5	21.7	33.4	46.3	60.4	75.0	90.2	129	
chloride (3-chloropropene)	C ₃ H ₅ Cl	-70.0	-52.0	-42.9	-32.8	-21.2	-14.1	-4.5	10.4	27.5	-136.4	
isopropyl ether	C ₄ H ₁₀ O	-43.7	-23.1	-12.9	-1.8	+10.9	18.7	29.0	44.3	61.7	79.5	
isobutylene	C ₄ H ₈	-2.0	+25.3	38.3	52.1	67.4	76.2	89.5	106.0	129.8	-80	
n-propyl ether	C ₄ H ₁₀ O	-39.0	-18.2	-7.9	+3.7	16.4	25.0	35.8	52.4	71.4	90.5	
4-Allylphenol	C ₉ H ₁₀ O	85.0	113.9	127.0	142.8	158.5	169.4	183.7	204.0	226.2	248.0	
iso-Amyl acetate	C ₈ H ₁₆ O ₂	0.0	+23.7	35.2	47.8	61.1	71.0	83.2	101.3	121.5	142.0	
n-Amyl alcohol	C ₅ H ₁₂ O	+13.6	34.7	44.9	55.8	68.0	75.5	85.8	102.0	119.8	137.8	
iso-Amyl alcohol	C ₅ H ₁₂ O	+10.0	30.9	40.8	51.7	63.4	71.0	80.7	95.8	113.7	130.6	
iso-Amyl alcohol (2-pentanol)	C ₅ H ₁₂ O	+1.5	22.1	32.3	42.6	54.1	61.5	70.7	85.7	102.3	119.7	
tert-Amyl alcohol	C ₅ H ₁₂ O	-12.9	+7.2	17.2	27.9	38.8	49.7	60.7	75.7	93.7	111.9	
iso-Amyl acetate	C ₈ H ₁₆ O ₂	29.0	55.8	69.2	83.8	100.0	110.4	124.1	145.2	168.0	193.0	
iso-Amyl acetate	C ₈ H ₁₆ O ₂	72.0	104.5	121.6	139.7	158.3	171.4	186.8	210.2	235.0	262.0	
bromide (1-bromo-3-methylbutane)	C ₅ H ₁₁ Br	-20.4	+2.1	13.6	26.1	39.8	48.7	60.4	78.7	99.4	120.4	
n-butyl alcohol	C ₄ H ₁₀ O	21.2	47.1	59.9	74.0	90.0	99.0	113.1	133.2	155.3	178.6	
formate	C ₄ H ₈ O ₂	-17.5	+5.4	17.1	30.0	44.0	53.3	65.4	83.2	102.7	123.3	
iodide (1-iodo-3-methylbutane)	C ₅ H ₁₁ I	-2.5	+21.9	34.1	47.4	62.3	71.9	84.4	103.8	125.8	148.2	
isobutylene	C ₄ H ₈	14.8	40.1	52.8	66.4	81.8	91.7	104.4	124.2	146.0	168.8	
Amyl isopropyl ether	C ₈ H ₁₈ O	+8.5	33.7	46.3	60.0	75.5	85.2	97.6	117.3	138.4	160.2	
iso-Amyl isovalerate	C ₈ H ₁₆ O ₂	27.0	54.4	68.6	83.8	100.6	110.5	125.1	146.1	169.5	194.0	
n-Amyl isovalerate	C ₈ H ₁₆ O ₂	61.3	110.0	124.0	139.7	155.8	165.2	180.5	203.1	227.4	253.2	
iso-Amyl isovalerate	C ₈ H ₁₆ O ₂	75.6	104.9	118.9	134.4	151.7	162.6	177.0	198.1	222.7	247.9	
nitrate	C ₈ H ₁₅ NO ₃	+5.2	28.8	40.3	53.5	67.4	76.3	88.6	106.7	128.5	147.5	
4-tert-Amylphenol	C ₁₀ H ₁₂ O	109.8	125.5	142.3	160.3	172.6	189.0	213.0	239.5	268.0	293	
Acetone	C ₃ H ₆ O	62.6	91.6	106.0	121.8	139.3	149.0	164.2	185.1	210.5	235.3	
Acetonitrile	C ₂ H ₃ N	-8.0	+15.0	28.0	41.0	55.8	65.2	77.5	96.3	117.7	140.0	
Aniline	C ₆ H ₆ N	34.8	57.9	69.4	82.0	96.7	106.0	119.9	140.1	161.9	184.4	
2-Anilinoethanol	C ₈ H ₁₀ NO	104.0	134.3	149.6	165.7	183.7	194.0	209.5	230.6	254.5	279.6	
Anisole	C ₆ H ₆ O	73.2	102.6	117.8	133.5	150.5	161.7	176.7	199.0	223.0	248.0	
n-Propyl alcohol	C ₃ H ₈ O	61.0	88.0	101.7	116.1	132.0	142.1	155.2	175.3	197.3	218.5	
Acetone	C ₃ H ₆ O	145.0	175.5	187.2	201.9	217.5	231.0	250.0	279.0	310.2	342.0	
Acetone	C ₃ H ₆ O	190.0	219.4	234.2	248.3	264.3	279.3	295.0	314.4	346.2	379.9	
Acetic acid	C ₂ H ₄ O ₂	178.3	210.4	225.3	242.4	260.0	271.6	286.5	309.4	332.8	356.5	
Acetaldehyde	C ₂ H ₄ O	33.3	58.4	71.6	85.0	100.2	110.9	123.0	142.1	163.4	185.0	
Acetone	C ₃ H ₆ O	103.5	135.7	151.5	168.3	187.9	199.8	216.0	240.0	266.1	293.0	
Benzaldehyde (α,α-Dichlorobenzaldehyde)	C ₇ H ₅ Cl ₂ O	35.4	64.0	78.7	94.3	112.1	123.4	138.3	160.7	182.0	214.0	
Benzaldehyde	C ₇ H ₆ O	26.2	50.1	62.0	75.0	90.1	99.4	112.5	131.7	154.1	179.0	
Benzonitrile	C ₆ H ₅ N	225.0	274.5	297.2	322.5	350.0	368.0	390.0	426.5	465.0	505.0	
Benzene	C ₆ H ₆	-36.7	-19.6	-11.5	-2.6	+7.4	15.4	26.1	42.2	60.4	80.1	
Benzenesulfonamide	C ₆ H ₅ SO ₂ NH ₂	65.9	96.5	112.0	129.0	147.0	158.2	174.5	198.0	224.0	251.5	
Benzoic acid	C ₇ H ₆ O ₂	128.4	165.2	185.0	202.8	224.5	238.2	255.8	283.5	314.3	347.0	
Benzoic acid	C ₇ H ₆ O ₂	96.0	119.5	132.1	146.7	162.6	172.8	186.2	205.8	227.0	249.2	
Benzoic anhydride	C ₁₄ H ₁₀ O ₃	143.8	180.0	198.0	218.0	239.8	252.7	270.4	299.1	328.8	360.0	
Benzene	C ₆ H ₆	135.6	170.2	188.1	207.0	227.6	241.7	258.0	284.4	313.5	343.0	
Benzonitrile	C ₆ H ₅ N	28.2	55.3	69.2	83.4	99.6	109.8	123.5	144.1	166.7	190.6	
Benzophenone	C ₁₂ H ₁₀ O	108.2	141.7	157.6	175.8	195.7	208.2	224.4	249.8	276.8	305.4	
Benzoyl chloride (α,α,α-Trichlorobenzoyl chloride)	C ₇ H ₃ Cl ₃ O	45.8	75.7	87.6	102.7	119.8	130.0	144.3	165.6	189.2	213.5	
Benzoyl chloride (α,α,α-Trifluorobenzoyl chloride)	C ₇ H ₃ F ₃ O	-32.0	-10.3	+0.4	12.2	25.7	34.0	45.3	62.5	82.0	102.2	
Benzoyl bromide	C ₇ H ₅ BrO	47.0	75.4	89.8	105.4	122.6	133.4	147.7	169.2	193.7	218.5	
chloride	C ₇ H ₅ ClO	32.1	59.1	73.0	87.6	103.8	114.7	128.0	149.5	172.8	197.2	
nitrate	C ₇ H ₅ NO ₃	44.5	71.7	85.5	100.2	116.6	127.0	141.0	161.3	185.0	208.0	
Benzyl acetate	C ₉ H ₁₀ O ₂	45.0	73.4	87.6	102.3	119.6	129.8	144.0	165.5	189.0	213.5	
alcohol	C ₉ H ₁₀ O	58.0	80.8	92.6	105.8	119.8	129.3	141.7	160.0	183.0	204.7	
Benzylamine	C ₉ H ₁₁ N	29.0	54.8	67.7	81.8	97.3	107.3	120.0	140.0	161.3	184.5	
Benzyl bromide (α-bromobenzene)	C ₇ H ₇ Br	32.2	59.6	73.4	88.3	104.8	115.6	129.8	150.8	175.2	198.5	
chloride (α-chlorobenzene)	C ₇ H ₇ Cl	22.0	47.8	60.8	75.0	90.7	100.5	114.2	134.0	155.8	179.4	
cinnamale	C ₉ H ₈	173.8	206.3	221.5	239.5	255.8	267.0	281.5	303.8	326.7	350.0	
Benzylchloroacetate	C ₉ H ₉ ClO ₂	45.3	70.2	83.2	96.7	111.8	121.3	133.5	152.0	173.0	194.3	
Benzyl ethyl ether	C ₁₁ H ₁₄ O	26.0	52.0	65.0	79.6	95.4	105.5	118.9	139.6	161.5	183.0	
isothiocyanate	C ₈ H ₇ NS	95.4	127.7	144.0	160.7	180.1	192.6	209.2	233.2	259.8	287.0	
Biphenyl	C ₁₂ H ₁₀	79.5	107.8	121.8	137.0	153.0	163.8	177.7	198.0	220.4	243.0	
1-Biphenyloxy-2,3-epoxypropane	C ₁₄ H ₁₂ O ₂	70.6	101.8	117.0	134.2	152.5	165.2	180.7	204.2	229.4	254.9	
Bornyl acetate	C ₁₃ H ₂₀ O ₂	135.3	169.9	187.2	205.6	226.3	239.7	255.0	280.4	309.8	340.0	
Bornyl n-butylate	C ₁₇ H ₃₀ O ₂	46.9	75.7	90.2	106.0	123.7	135.7	149.8	172.0	197.5	223.0	
formate	C ₁₃ H ₂₀ O ₂	74.0	103.4	118.0	133.8	150.7	161.8	176.4	198.0	222.2	247.0	
isobutylate	C ₁₃ H ₂₄ O ₂	47.0	74.8	89.3	104.0	121.2	131.7	145.8	166.4	190.2	214.0	
propionate	C ₁₃ H ₂₂ O ₂	70.0	99.8	114.0	130.0	147.2	157.6	172.2	194.2	218.2	243.0	
Branched acid	C ₁₃ H ₂₄ O ₂	64.6	93.7									

* Compiled from the extended tables published by D. R. Stull in *Ind. Eng. Chem.*, 39, 517 (1947). For information on fuels see Hibbard, *N.A.C.A. Research Mem.*, ES6121, 1956. For methane see Johnson (ed.), WADD-TR-60-56, 1960.

Compound		Pressure, mm. Hg										Molar heat of fusion, cal./g.
Name	Formula	1	5	10	20	40	60	100	200	400	760	
Temperature, °C.												
Bromobenzene	C ₆ H ₅ Br	+2.9	27.6	40.0	51.8	68.4	78.1	90.8	110.1	132.3	154.2	-30.7
4-Bromobiphenyl	C ₁₂ H ₉ Br	98.0	133.7	158.0	169.8	190.8	204.5	221.0	248.2	277.7	310.0	90.3
1-Bromo-2-nitrobenzene	C ₆ H ₄ (Br)(NO ₂)	23.7	43.4	55.8	67.2	79.5	87.0	97.6	112.1	128.3	145.0	
1-Bromo-3-nitrobenzene	C ₆ H ₄ (Br)(NO ₂)	+4.2	30.0	41.8	54.2	68.2	77.3	89.2	107.0	128.3	145.0	
cis-1-Bromo-1-butene	C ₄ H ₇ Br	-44.0	-23.2	-12.8	-1.4	+11.5	19.8	30.4	47.8	64.4	84.2	
trans-1-Bromo-1-butene	C ₄ H ₇ Br	-38.4	-17.0	-6.4	+3.4	18.4	27.2	38.1	55.7	73.0	94.7	-100.3
2-Bromo-1-butene	C ₄ H ₇ Br	-47.3	-27.0	-16.8	-5.3	+7.2	15.4	26.3	42.8	61.9	81.0	-130.4
cis-2-Bromo-2-butene	C ₄ H ₇ Br	-39.0	-17.9	-7.2	+4.0	17.7	26.2	37.5	54.3	74.0	93.9	-111.2
trans-2-Bromo-2-butene	C ₄ H ₇ Br	-45.0	-24.1	-13.8	-2.4	+10.5	18.7	29.9	46.3	66.6	85.5	-114.6
1-Bromo-1-chlorobutane	C ₄ H ₈ BrCl	32.0	59.5	72.7	87.8	103.8	114.4	128.0	149.5	172.4	194.9	
1-Bromo-2-chlorobutane	C ₄ H ₈ BrCl	-34.0	-18.0	-9.4	0.0	+10.4	17.0	28.0	44.7	63.4	82.7	16.6
2-Bromo-4,6-dichlorophenol	C ₆ H ₃ BrCl ₂ O	-28.8	-7.0	+4.1	15.0	29.7	38.0	49.5	66.8	86.0	106.7	-18.6
1-Bromo-4-ethylbenzene	C ₈ H ₉ Br	84.0	115.6	130.8	147.7	165.8	177.4	193.2	216.5	242.0	268.0	
(2-Bromomethyl)-benzene	C ₆ H ₉ Br	30.4	62.5	74.0	90.2	108.3	121.0	135.5	156.5	182.0	206.0	-85.0
2-Bromomethyl-2-chloroethyl ether	C ₄ H ₈ BrClO	46.0	76.7	90.5	105.8	123.3	133.4	148.2	168.2	194.6	219.0	
(2-Bromomethyl)-cyclohexane	C ₆ H ₁₁ Br	36.5	63.2	76.3	90.8	106.4	116.4	129.8	150.0	172.3	195.8	
1-Bromocyclohexane	C ₆ H ₁₁ Br	32.7	66.4	80.5	95.8	113.0	123.7	138.0	160.0	184.2	213.0	
Bromoform (tribromomethane)	CHBr ₃	-93.4	-77.8	-68.4	-58.0	-46.1	-31.9	-17.2	-1.1	+15.0	+38.0	-130
1-Bromocyclopentane	C ₅ H ₉ Br	22.0	34.0	48.0	63.4	78.4	89.9	106.1	127.9	150.5	175.0	8.5
2-Bromo-1-cyclopentanol	C ₅ H ₉ BrO	84.2	117.5	133.6	150.2	170.2	183.5	198.8	224.2	250.0	281.1	5.3
3-Bromopyridine	C ₅ H ₄ BrN	100.0	135.4	152.3	171.8	193.8	207.0	223.5	251.0	280.2	311.0	95
2-Bromotoluene	C ₇ H ₇ Br	16.8	42.0	55.2	69.1	84.1	94.1	107.8	127.7	150.0	173.4	
3-Bromotoluene	C ₇ H ₇ Br	24.4	49.7	62.3	76.0	91.0	100.0	112.9	133.4	157.0	181.0	-38
4-Bromotoluene	C ₇ H ₇ Br	14.8	50.8	64.0	78.1	93.9	104.1	117.8	138.0	160.0	183.7	39.8
2-Bromo-2,4,6-trimethylphenol	C ₉ H ₉ BrO	10.3	47.5	61.1	75.2	91.8	102.3	116.4	137.4	160.2	185.7	28.5
1,2-Dibromobenzene (methyl silane)	C ₆ H ₄ Br ₂	112.4	145.2	163.2	181.8	200.5	213.0	229.3	253.0	278.0	305.8	
1,3-Butadiene	C ₄ H ₆	37.5	65.0	78.8	94.0	110.4	121.6	135.7	154.4	181.0	204.7	+9.5
n-Butane	C ₄ H ₁₀	-89.0	-72.7	-64.2	-54.9	-44.3	-37.5	-28.3	-14.2	+1.8	18.5	
iso-Butane	C ₄ H ₁₀	-102.8	-87.6	-79.2	-71.0	-61.3	-55.1	-46.8	-33.9	-19.3	-4.5	-108.9
1,3-Butadiene (2-methylpropene)	C ₄ H ₆	-101.5	-85.7	-77.4	-68.9	-59.1	-52.8	-44.2	-31.7	-16.3	-5.3	-135
1,2,3-Butanetriol	C ₄ H ₈ O ₃	-109.2	-94.1	-86.4	-77.9	-68.4	-62.4	-54.1	-41.5	-27.1	-11.7	-105.4
1,2,3-Butanetriol	C ₄ H ₈ O ₃	22.2	67.5	85.3	100.0	117.4	127.5	141.2	161.0	183.8	206.5	77
n-Butane	C ₄ H ₁₀	102.0	132.0	146.0	161.0	178.0	188.0	202.5	222.0	243.5	264.0	
cis-2-Butene	C ₄ H ₈	-104.8	-89.4	-81.4	-73.0	-63.4	-57.2	-48.9	-36.2	-21.7	-6.3	-130
trans-2-Butene	C ₄ H ₈	-96.4	-81.1	-73.4	-64.6	-54.7	-48.4	-39.8	-26.8	-12.0	+3.7	-134.9
3-Butenenitrile	C ₄ H ₅ N	-99.4	-84.0	-76.3	-67.5	-57.4	-51.3	-42.7	-29.7	-14.0	+0.9	-105.4
iso-Butyl acetate	C ₆ H ₁₂ O ₂	-19.6	+2.9	14.1	28.4	40.0	48.8	60.2	75.0	94.0	116.0	
n-Butyl acetate	C ₆ H ₁₂ O ₂	-21.2	+1.4	12.8	25.3	39.2	48.0	59.7	77.4	97.5	119.0	-91.9
alcohol	C ₄ H ₁₀ O	-0.5	+1.4	12.8	25.3	39.2	48.0	59.7	77.4	97.5	119.0	-91.9
iso-Butyl alcohol	C ₄ H ₁₀ O	-1.2	+2.0	30.2	48.6	63.4	72.6	85.1	104.0	125.2	147.4	-64.6
sec-Butyl alcohol	C ₄ H ₁₀ O	-9.0	+11.6	21.7	41.5	53.4	60.3	70.1	84.3	100.8	117.5	-79.9
tert-Butyl alcohol	C ₄ H ₁₀ O	-12.2	+7.2	16.9	32.3	44.1	51.7	61.5	73.9	91.4	108.0	-108
iso-Butyl amine	C ₄ H ₁₁ N	-20.4	-3.0	+5.5	14.3	24.5	34.1	45.2	54.1	67.9	83.9	-114.7
n-Butylbenzene	C ₁₀ H ₁₄	-50.0	-31.0	-21.0	-10.3	+1.3	31.0	39.4	52.7	68.0	82.9	23.3
iso-Butylbenzene	C ₁₀ H ₁₄	22.7	43.8	62.0	76.3	92.4	102.6	116.2	136.9	159.2	183.1	-83.0
sec-Butylbenzene	C ₁₀ H ₁₄	14.1	40.5	53.7	67.8	83.3	93.3	107.0	127.2	149.4	172.0	-51.5
tert-Butylbenzene	C ₁₀ H ₁₄	13.6	44.2	57.0	70.6	86.2	96.0	109.5	129.5	153.3	177.5	-75.5
iso-Butyl benzoate	C ₁₀ H ₁₂ O ₂	64.0	93.6	108.6	124.2	141.8	152.0	166.4	188.2	212.8	237.0	-58
n-Butyl benzoate	C ₁₀ H ₁₂ O ₂	33.0	62.6	77.6	93.2	110.2	121.4	136.2	157.8	181.2	205.0	-112.4
iso-Butyl bromide (1-bromobutane)	C ₄ H ₉ Br	-33.0	-11.2	-0.3	+11.6	24.8	33.4	44.7	62.0	81.7	101.6	-112.4
tert-Butyl bromide	C ₄ H ₉ Br	+4.6	30.0	42.2	56.1	71.7	81.3	94.0	113.9	135.7	158.9	
Butyl carbitol (diethylene glycol butyl ether)	C ₁₀ H ₂₀ O	70.0	95.7	107.8	120.5	135.5	146.0	159.6	181.2	205.0	231.2	65
n-Butyl chloride (1-chlorobutane)	C ₄ H ₉ Cl	-47.0	-28.9	-16.6	-7.4	+3.0	13.0	24.0	40.0	58.0	77.8	-123.1
iso-Butyl chloride (2-chlorobutane)	C ₄ H ₉ Cl	-53.8	-34.3	-24.5	-13.8	-1.9	+5.9	16.0	32.0	50.0	68.9	-131.2
tert-Butyl chloride	C ₄ H ₉ Cl	-60.2	-39.8	-29.2	-17.7	-5.0	+3.4	14.2	31.5	50.0	68.0	-131.3
sec-Butyl chloroacetate	C ₆ H ₁₁ ClO ₂	17.0	41.8	54.6	68.2	83.6	93.9	105.3	124.1	146.0	167.8	-20.5
2-tert-Butyl-4-cresol	C ₁₀ H ₁₂ O	70.0	95.0	112.0	127.2	143.9	153.7	167.0	187.8	210.0	232.0	
4-tert-Butyl-2-cresol	C ₁₀ H ₁₂ O	74.3	103.7	118.0	134.0	150.8	161.7	176.2	197.8	221.8	247.0	
iso-Butyl dichloroacetate	C ₆ H ₁₀ Cl ₂ O ₂	28.6	54.3	67.5	81.4	96.7	106.6	119.8	139.2	160.0	183.0	
2,3-Butylene glycol (2,3-butanediol)	C ₄ H ₁₀ O ₂	44.0	65.4	80.3	95.4	107.8	116.3	127.8	145.6	164.0	182.0	22.5
2-Butyl-2-ethylbutane-1,3-diol	C ₈ H ₁₈ O ₂	94.1	122.6	136.8	151.2	167.8	178.0	191.9	212.0	233.5	255.0	
2-tert-Butyl-4-ethylphenol	C ₁₂ H ₁₆ O	76.3	106.2	121.0	137.0	154.0	165.4	179.0	200.3	223.8	247.8	
n-Butyl formate	C ₆ H ₁₂ O ₂	-26.4	-7.7	+6.1	18.0	31.4	39.0	51.0	67.9	85.2	104.0	
iso-Butyl formate	C ₆ H ₁₂ O ₂	-32.7	-11.4	-0.8	+11.0	24.1	32.4	43.4	60.0	79.0	98.2	-95.3
sec-Butyl glycolate	C ₆ H ₁₂ O ₄	-34.4	-13.3	-3.1	+6.4	21.9	29.6	40.2	56.8	75.2	93.6	
iso-Butyl iodide (1-iodo-2-methylpropane)	C ₄ H ₉ I	28.3	53.6	66.0	79.8	94.2	104.0	116.4	135.5	155.6	177.5	
isobutyrate	C ₄ H ₈ O ₂	-17.0	+5.8	17.0	29.8	42.8	51.8	63.5	81.0	100.3	120.4	-90.7
isovalerate	C ₅ H ₁₀ O ₂	+4.1	28.0	39.9	52.4	67.2	75.9	88.0	106.3	126.3	147.5	-80.7
isovalinate	C ₅ H ₁₀ O ₂	16.0	41.2	53.8	67.7	82.7	92.4	105.2	124.8	146.4	168.7	
naphthylacetone (1-isovalerone)	C ₁₁ H ₁₄ O	43.0	72.1	105.9	120.2	136.2	147.0	160.2	181.8	205.5	229.9	
2-sec-Butylphenol	C ₁₀ H ₁₂ O	136.0	167.9	184.0	201.6	219.7	231.5	246.7	269.7	294.0	320.0	
2-tert-Butylphenol	C ₁₀ H ₁₂ O	57.4	86.0	100.8	116.1	133.4	143.9	157.3	179.7	203.8	228.0	
4-iso-Butylphenol	C ₁₀ H ₁₂ O	56.4	84.2	98.1	113.0	129.2	140.0	153.5	173.8	196.3	220.0	
4-sec-Butylphenol	C ₁₀ H ₁₂ O	72.1	100.9	115.5	130.3	147.2	157.0	171.2	192.1	214.7	237.0	
4-tert-Butylphenol	C ₁₀ H ₁₂ O	71.4	100.5	114.8	130.3	147.8	157.9	172.4	194.3	217.6	242.1	
2-(4-tert-Butylphenoxy)ethyl acetate	C ₁₂ H ₁₆ O ₃	70.0	99.2	114.0	129.5	146.0	156.0	170.2	191.5	214.6	238.0	
4-tert-Butylphenyl dichlorophosphate	C ₁₀ H ₇ Cl ₂ O ₄ P	118.0	150.0	165.8	183.3	201.5	212.8	228.0	250.3	277.4	304.4	99
tert-Butyl phenyl ketone (pivalophenone)	C ₁₁ H ₁₄ O	96.0	129.6	146.0	164.0	184.3	197.2	214.3.4				

Compound	Name	Formula	Pressure, mm. Hg										Heat of fusion, °C.
			1	5	10	20	40	60	100	200	400	760	
			Temperature, °C.										
iso-Butyric acid	<chem>CH3CH2CH2COOH</chem>	14.7	39.5	51.2	64.6	77.6	86.3	93.0	115.6	134.5	154.5		
Butyronitrile	<chem>CH3CH2CH2CN</chem>	-20.0	+2.1	13.4	25.7	38.4	47.3	59.0	76.7	96.6	117.5	-0	
iso-Valerophenone	<chem>CH3CH2CH2CH2COCH3</chem>	54.3	87.0	101.4	116.8	133.8	144.6	158.0	176.1	204.2	230.0		
Camphene	<chem>C10H16</chem>	47.2	47.2	60.4	75.7	85.0	97.9	117.5	137.9	159.9	182.0	59	
Camphor	<chem>C15H24O</chem>	97.6	123.7	139.0	153.9	170.0	186.0	193.7	212.7	234.0	256.0		
Camphorquinone	<chem>C15H18O2</chem>	41.5	68.6	82.3	97.5	114.0	124.0	138.0	157.9	182.0	209.2	178.5	
Camphor	<chem>C15H24O</chem>	45.5	74.0	87.7	97.6	112.5	122.0	134.6	153.6	173.8	195.0		
Camphor	<chem>C15H24O</chem>	51.9	78.8	92.0	106.3	122.2	132.0	145.3	164.8	186.3	208.5		
Camphor	<chem>C15H24O</chem>	125.0	142.0	152.2	165.0	179.9	189.8	200.0	217.1	240.3	264.4	31.5	
Camphor	<chem>C15H24O</chem>	71.4	89.5	99.5	111.8	125.0	133.3	144.0	160.8	181.0	202.0		
Camphor	<chem>C15H24O</chem>	66.2	83.0	94.0	107.0	120.4	129.6	141.4	156.3	181.0	207.7	-35	
Camphor	<chem>C15H24O</chem>	34.5	56.4	68.0	83.7	95.7	112.3	127.2	137.2	157.8	182.1		
Camphor	<chem>C15H24O</chem>	9.2	34.6	47.5	61.7	76.9	86.8	99.8	119.7	141.0	163.7		
Camphor	<chem>C15H24O</chem>	32.8	56.4	70.0	83.3	95.7	112.3	127.2	137.2	157.8	182.1		
Camphor	<chem>C15H24O</chem>	73.4	92.0	101.2	116.2	130.0	138.0	148.0	168.0	188.0	208.0	-34.0	
Camphor	<chem>C15H24O</chem>	92.3	114.1	124.0	138.4	150.6	162.2	172.2	190.3	213.9	237.5	16	
Camphor	<chem>C15H24O</chem>	43.0	67.6	80.4	94.6	110.6	121.2	134.8	157.9	179.2	204.5		
Carbon dioxide	<chem>CO2</chem>	-134.3	-124.4	-119.5	-114.4	-108.6	-104.8	-100.2	-95.0	-85.7	-78.5	244.8	
Carbon dioxide	<chem>CO2</chem>	-75.8	-54.3	-44.7	-34.3	-22.5	-15.3	-5.1	+10.4	28.0	49.3	-110	
Carbon dioxide	<chem>CO2</chem>	-222.0	-217.2	-215.0	-212.8	-210.0	-208.1	-205.7	-201.3	-196.3	-191.3	-205.0	
Carbon dioxide	<chem>CO2</chem>	-117.1	-102.3	-95.0	-86.3	-76.0	-70.2	-61.7	-49.8	-35.6	-21.9		
Carbon dioxide	<chem>CO2</chem>	-132.4	-119.8	-113.3	-106.0	-98.3	-93.0	-85.9	-75.0	-62.7	-49.9	-138.8	
Carbon dioxide	<chem>CO2</chem>	-50.0	-30.0	-19.6	-8.2	+4.3	12.3	23.0	38.3	57.6	76.7	-22.0	
Carbon dioxide	<chem>CO2</chem>	-184.6	-174.1	-169.3	-164.3	-158.4	-153.4	-150.7	-143.6	-135.5	-127.7	-78.5	
Carbon dioxide	<chem>CO2</chem>	70.4	88.4	113.2	127.9	145.2	153.3	169.7	191.2	213.8	237.0	+0.5	
Carbon dioxide	<chem>CO2</chem>	57.4	86.1	100.0	116.1	133.0	149.8	157.3	179.2	203.5	227.5		
Carbon dioxide	<chem>CO2</chem>	83.6	113.3	127.0	143.2	159.8	170.7	185.5	206.8	229.8	254.0		
Carbon dioxide	<chem>CO2</chem>	-37.8	-16.0	-5.0	+7.2	20.9	29.1	40.2	57.8	77.5	97.7	-57	
Carbon dioxide	<chem>CO2</chem>	-9.8	+10.0	19.5	29.2	39.7	55.0	68.0	82.1	96.2	111.3	131.3	
Chloroacetic acid	<chem>ClCH2COOH</chem>	70.7	89.3	97.8	106.4	116.1	122.0	130.7	149.0	169.0	189.0	210.0	
Chloroacetic acid	<chem>ClCH2COOH</chem>	43.0	68.3	81.0	94.2	109.2	118.3	130.7	149.0	169.0	189.0	210.0	
Chloroacetic acid	<chem>ClCH2COOH</chem>	67.2	94.1	108.0	122.4	138.2	148.0	159.8	177.8	197.0	217.0	61.3	
Chloroacetic acid	<chem>ClCH2COOH</chem>	46.3	72.3	84.8	99.2	115.6	125.7	139.5	160.8	183.0	207.0	46	
Chloroacetic acid	<chem>ClCH2COOH</chem>	63.5	89.8	102.0	116.7	133.6	144.1	158.0	179.5	203.5	228.5	-10.4	
Chloroacetic acid	<chem>ClCH2COOH</chem>	59.3	87.9	102.1	117.8	135.0	145.8	159.9	182.3	206.6	230.5	70.5	
Chloroacetic acid	<chem>ClCH2COOH</chem>	-13.0	+10.6	22.2	35.3	49.7	58.3	70.7	89.4	110.0	132.2	-45.3	
2-Chlorobenzoic acid	<chem>ClC6H4COOH</chem>	69.0	101.8	117.9	135.8	155.0	167.8	185.0	208.0	235.0	262.1	28.7	
2-Chlorobenzoic acid	<chem>ClC6H4COOH</chem>	0.0	24.7	37.1	50.6	65.9	75.4	88.7	108.3	130.0	152.2	-4.0	
2-Chlorobiphenyl	<chem>ClC6H4C6H5</chem>	89.3	109.8	134.7	151.2	169.9	182.1	199.0	219.6	243.8	267.5	34	
2-Chlorobiphenyl	<chem>ClC6H4C6H5</chem>	96.4	129.8	146.0	164.0	184.0	196.0	215.9	237.8	264.5	292.9	75.5	
Chlorodifluoromethane	<chem>ClCF2</chem>	70.0	95.6	104.0	121.3	133.4	144.4	155.2	173.8	193.2	212.0		
Chlorodifluoromethane	<chem>ClCF2</chem>	-122.8	-110.2	-103.7	-96.5	-88.6	-83.4	-76.4	-65.8	-53.6	-40.8	-160	
Chlorodifluoromethane	<chem>ClCF2</chem>	29.8	56.7	70.0	84.7	101.2	111.5	124.7	145.8	168.6	193.5		
2-(2-Chlorophenyl) ethanol	<chem>ClC6H4CH2CH2OH</chem>	45.8	72.8	86.5	101.5	117.8	127.8	141.8	162.0	185.5	208.0		
2-(2-Chlorophenyl) ethanol	<chem>ClC6H4CH2CH2OH</chem>	53.0	78.9	90.7	104.1	118.4	127.5	139.5	157.5	177.5	198.0		
2-(2-Chlorophenyl) ethanol	<chem>ClC6H4CH2CH2OH</chem>	56.2	83.7	97.6	112.2	127.8	139.0	150.7	169.0	190.5	212.4		
1-Chloro-2-ethylbenzene	<chem>ClC6H4CH2CH3</chem>	17.2	43.0	56.1	70.3	86.2	96.4	110.0	130.2	152.2	177.4	-80.3	
1-Chloro-2-ethylbenzene	<chem>ClC6H4CH2CH3</chem>	18.6	45.2	58.1	73.0	89.2	99.6	113.6	133.8	156.7	181.1	-53.3	
1-Chloro-2-ethylbenzene	<chem>ClC6H4CH2CH3</chem>	19.2	46.4	60.0	75.5	91.8	102.0	116.0	137.0	159.8	184.3	-62.6	
2-Chloroethyl chloroacetate	<chem>ClCH2CH2COOCCl</chem>	46.0	72.1	86.0	100.0	116.0	126.2	140.0	159.8	182.2	205.0		
2-Chloroethyl 2-chloropropyl ether	<chem>ClCH2CH2OCH2CH(Cl)CH3</chem>	24.7	50.1	63.0	77.2	92.4	102.2	115.8	135.7	156.5	180.0		
2-Chloroethyl 2-chloropropyl ether	<chem>ClCH2CH2OCH2CH(Cl)CH3</chem>	29.8	56.5	70.0	84.8	101.1	111.8	125.6	146.3	169.8	194.1		
2-Chloroethyl 2-chloropropyl ether	<chem>ClCH2CH2OCH2CH(Cl)CH3</chem>	62.3	89.4	106.0	121.8	139.6	150.0	164.8	186.3	210.8	235.0		
Chloroform (trichloromethane)	<chem>CHCl3</chem>	-63.0	-39.1	-29.7	-19.6	-9.7	-1.1	+0.5	10.4	25.9	42.7	61.3	
1-Chloronaphthalene	<chem>ClC10H7</chem>	84.6	104.8	118.4	133.2	149.4	160.0	173.5	198.1	224.2	250.6	-20	
1-Chloronaphthalene	<chem>ClC10H7</chem>	82.0	114.3	129.0	145.0	162.0	173.5	188.1	210.2	234.5	259.3		
1-Chloronaphthalene	<chem>ClC10H7</chem>	14.1	38.2	51.2	65.9	82.0	92.0	104.0	126.4	149.8	174.5	7	
1-Chloronaphthalene	<chem>ClC10H7</chem>	44.2	72.0	86.1	101.7	118.0	129.4	143.0	164.8	188.7	214.0	32.5	
1-Chloronaphthalene	<chem>ClC10H7</chem>	49.8	78.2	92.2	108.1	125.0	136.1	150.7	170.0	196.0	220.0	42	
2-Chloro-3-phenylphenol	<chem>ClC6H4C6H4OH</chem>	118.0	152.2	169.7	186.7	207.4	219.6	237.0	261.3	290.7	317.0	+4	
2-Chloro-3-phenylphenol	<chem>ClC6H4C6H4OH</chem>	119.8	153.7	170.7	189.8	208.2	228.0	257.1	281.6	309.4	337.0		
Chloroform (trichloromethane)	<chem>CHCl3</chem>	-25.5	-3.3	+7.8	20.0	33.6	42.3	53.8	71.8	91.8	111.9	-64	
1-Chloropyridine	<chem>ClC5H4N</chem>	-81.3	-63.4	-44.1	-24.0	-12.7	-5.1	+1.3	18.0	37.0	57.0	-99.0	
1-Chloropyridine	<chem>ClC5H4N</chem>	13.3	38.8	51.7	65.8	81.7	91.6	104.6	125.0	147.7	170.2		
1-Chloropyridine	<chem>ClC5H4N</chem>	25.5	51.3	65.2	80.0	96.5	107.2	121.2	142.2	165.7	190.0	0	
1-Chlorotetradecane	<chem>ClC14H29</chem>	28.0	54.5	67.5	82.0	98.0	108.5	122.0	143.5	166.0	191.0	-15.0	
1-Chlorotetradecane	<chem>ClC14H29</chem>	98.5	131.8	148.2	166.2	187.0	199.8	215.5	240.3	267.5	296.0	+0.9	
1-Chlorotetradecane	<chem>ClC14H29</chem>	+5.4	30.6	43.2	56.9	72.0	81.4	94.7	115.0	137.1	159.3		
1-Chlorotetradecane	<chem>ClC14H29</chem>	+4.8	30.3	43.2	57.4	73.0	83.2	96.3	116.6	139.7	162.3		
1-Chlorotetradecane	<chem>ClC14H29</chem>	+5.3	31.0	43.8	57.8	73.5	83.5	96.3	117.1	139.8	162.3	+7.3	
Chloroethoxyethane	<chem>ClCH2CH2OCH2CH3</chem>	-4.9	+19.8	32.2	45.5	60.2	69.3	82.3	101.0	123.6	146.3		
1-Chloro-1,1,2-trifluoroethane	<chem>ClCF2CH2F</chem>	-116.0	-102.5	-95.9	-88.2	-79.4	-71.1	-61.1	-55.0	-47.7	-27.9	-157.5	
Chloroethoxyethane	<chem>ClCH2CH2OCH2CH3</chem>	-149.5	-139.2	-134.1	-128.5	-121.9	-117.3	-111.1	-102.9	-92.7	-81.9		
Chloroethoxyethane	<chem>ClCH2CH2OCH2CH3</chem>	-62.8	-43.6	-34.0	-23.2	-11.4	-4.0	+6.0	21.0	39.4	57.9		
trans-Chloroacetic acid	<chem>ClCH=CHCOOH</chem>	127.5	157.8	173.0	189.5	207.1	217.8	232.4	253.3	276.7	300.0	139	
trans-Chloroacetic acid	<chem>ClCH=CHCOOH</chem>	72.6	102.5	117.6	133.7	151.0	162.0	177.8	199.8	224.6	250.0	33	
Citronellaldehyde	<chem>C10H16O</chem>	76.1	105.8	120.0	135.7	152.2	163.7	177.7	199.3	222.4	246.0	-7.5	
Citronellaldehyde	<chem>C10H16O</chem>	47.1	74.8	88.9	103.8	120.3	131.3	145.4	165.8	189.8	213.5		
Citronellaldehyde	<chem>C10H16O</chem>	61.7	90.0	103.9	119.4	135.9	146.3	160.0	181.8	205.0	228.0		
Citronellaldehyde	<chem>C10H16O</chem>	44.0	71.4	84.8	99.8	116.1	126.4	140.1	160.0	183.8	206.5		
Citronellaldehyde	<chem>C10H16O</chem>	99.5	127.3	141.4	155.6	171.9	182.1	195.4	214.5	236.6	257.0		
Citronellaldehyde	<chem>C10H16O</chem>	64.4	93.0	107.0	121.5	137.2	147.2	159.8	179.0	201.0	221.5		
Citronellaldehyde	<chem>C10H16O</chem>	74.7	100.8	115.0	126.0	140.5	149.7	161.0	178.0	197.8	217.0		
Coumarin	<chem>C9H6O2</chem>	106.0	137.2	153.4	170.0	189.0	200.5	216.5	240.0	264.7	291.0	70	

Compound	Name	Formula	Pressure, mm. Hg											Molal point, °C.
			Temperature, °C.											
			1	5	10	20	40	60	100	200	400	760		
o-Cresol (2-cresol; 2-methylphenol).....	C ₇ H ₈ O		38.2	64.0	76.7	90.5	105.8	115.5	127.4	146.7	168.4	190.8	50.8	
m-Cresol (3-cresol; 3-methylphenol).....	C ₇ H ₈ O		32.0	76.0	87.6	101.4	116.0	125.8	138.0	157.3	179.0	202.8	48.9	
p-Cresol (4-cresol; 4-methylphenol).....	C ₇ H ₈ O		33.0	76.5	88.4	102.3	117.7	127.0	140.0	157.3	179.4	201.8	53.5	
o-Crotonic acid.....	C ₄ H ₆ O ₂		33.5	57.4	69.0	82.0	96.0	104.5	116.9	133.9	152.2	171.9	15.5	
trans-Crotonic acid.....	C ₄ H ₆ O ₂		.....	.....	80.0	93.0	107.8	116.7	128.0	144.0	165.3	183.0	72	
cro-Crotononitrile.....	C ₄ H ₅ N		.....	.....	14.0	16.4	30.0	38.5	50.1	64.0	88.0	108.0	.....	
trans-Crotononitrile.....	C ₄ H ₅ N		-19.5	+3.5	15.0	27.0	41.0	50.9	62.8	81.1	101.5	122.0	.....	
Cumene.....	C ₉ H ₁₀		+2.9	25.8	38.3	51.2	64.1	75.4	88.1	107.3	129.2	152.4	-94.0	
4-Cumylaldehyde.....	C ₉ H ₁₀ O		60.0	88.2	102.2	117.6	134.2	145.0	158.0	180.0	205.2	227.0	.....	
Cumylal.....	C ₉ H ₁₀ O		58.0	87.3	102.0	117.9	135.2	146.0	160.0	182.8	208.7	232.0	.....	
Cumylal alcohol.....	C ₉ H ₁₀ O		74.2	105.7	118.0	135.0	150.3	161.7	176.2	197.9	221.7	246.3	.....	
2-Cyano-2-methyl acetone.....	C ₅ H ₈ NO ₂		42.0	68.7	82.0	96.2	111.8	121.5	139.8	152.2	173.4	195.2	.....	
Cyanosene.....	C ₅ H ₄ N ₂		-95.8	-83.2	-76.8	-70.1	-62.7	-57.9	-51.0	-42.0	-33.0	-25.0	-34.4	
chloride.....	C ₅ H ₄ N ₂ Cl ₂		-35.7	-18.3	-10.0	-1.6	+4.4	+14.7	+22.4	+33.8	+46.0	+61.5	54	
iodide.....	C ₅ H ₄ N ₂ I ₂		-74.7	-61.4	-53.0	-46.1	-37.5	-32.1	-24.9	-14.1	-2.3	+18.1	-4.5	
Cyclobutane.....	C ₄ H ₈		25.2	47.2	57.7	68.4	80.3	88.0	97.4	111.5	126.1	141.1	.....	
Cyclobutene.....	C ₄ H ₆		-92.0	-76.0	-67.9	-58.7	-48.4	-38.0	-27.8	-18.9	-3.4	+12.9	-50	
Cyclobutene.....	C ₄ H ₆		-99.1	-83.4	-73.4	-64.6	-54.4	-43.0	-31.2	-20.0	-12.2	+2.4	.....	
Cyclobutene.....	C ₄ H ₆		-45.5	-25.4	-15.9	-5.0	+4.7	+14.7	+25.5	+42.0	+60.8	+80.7	+4.4	
Cyclobutanone.....	C ₄ H ₆ O		50.4	77.2	90.0	104.0	119.0	129.0	142.7	161.7	183.5	205.4	.....	
Cyclobutanol.....	C ₄ H ₈ O		21.0	44.0	56.0	68.0	80.0	91.0	105.7	121.7	141.4	161.0	23.9	
Cyclobutanone.....	C ₄ H ₆ O		+1.4	25.4	35.7	52.5	67.8	77.5	90.4	110.5	132.5	155.4	-45.0	
2-Cyclohexyl-4,4-dimethylpentane.....	C ₁₈ H ₃₄		132.8	161.8	175.9	191.2	206.7	216.0	229.0	246.7	269.8	291.5	.....	
Cyclopentane.....	C ₅ H ₁₀		-68.0	-49.6	-40.4	-30.1	-18.6	-11.3	-1.3	+13.0	+31.0	+49.5	-95.7	
Cyclopentene.....	C ₅ H ₈		-118.0	-104.2	-97.5	-90.3	-82.3	-77.0	-70.0	-64.9	-59.5	-53.5	-126.6	
Cymene.....	C ₁₀ H ₁₄		17.5	45.9	57.0	71.1	87.0	97.2	110.8	131.4	153.5	177.2	-68.2	
cin-Decalin.....	C ₁₀ H ₁₆		22.5	50.1	64.2	79.8	97.5	108.0	125.2	145.4	169.9	194.6	-0.5	
trans-Decalin.....	C ₁₀ H ₁₆		-0.5	+30.4	47.2	65.3	85.7	104.4	114.6	126.2	140.1	156.7	-30.7	
Decane.....	C ₁₀ H ₂₂		14.5	42.3	55.7	69.9	85.9	95.5	108.4	128.4	150.6	174.1	-29.7	
Decene.....	C ₁₀ H ₁₈		44.2	71.9	85.8	100.7	117.1	127.8	142.0	163.2	186.7	211.0	+3.5	
1-Decene.....	C ₁₀ H ₁₈		14.7	40.3	53.7	67.8	83.3	93.5	106.5	128.7	149.2	172.0	.....	
Decyl alcohol.....	C ₁₀ H ₂₁ O		69.5	97.3	111.3	125.8	142.1	152.0	165.8	186.2	208.8	231.0	+7	
Decyltrimethylsilane.....	C ₁₃ H ₂₈ Si		67.4	96.4	111.0	126.5	144.0	154.3	169.5	191.0	215.5	240.0	.....	
Dichloroacetic acid.....	C ₂ H ₂ Cl ₂ O ₂		91.7	122.0	137.3	155.0	171.0	181.5	197.5	219.5	244.5	269.0	.....	
Diacetylbromine.....	C ₄ H ₆ Br ₂ O ₂		123.5	156.2	173.5	192.0	212.0	224.5	241.5	265.2	295.0	321.0	60	
Diacetamide.....	C ₄ H ₈ Br ₂ N ₂ O ₂		70.0	95.0	108.0	122.4	138.2	148.0	160.4	180.8	202.0	225.0	78.5	
Diacetylene (1,3-butadiene).....	C ₄ H ₂		-82.5	-68.0	-61.2	-53.8	-45.9	-41.0	-34.0	-20.9	-4.1	+9.7	-54.9	
Diallyldichlorosilane.....	C ₄ H ₆ Cl ₂ Si ₂		+9.5	34.8	47.4	61.3	76.4	86.5	99.7	119.4	142.0	165.3	.....	
Diallyl sulfide.....	C ₄ H ₈ S		-9.5	+14.6	26.6	39.7	54.3	63.7	75.8	94.6	116.1	138.4	-85	
Dibenzyl ether.....	C ₁₄ H ₁₄ O		18.0	44.9	57.0	70.7	86.3	96.0	109.6	129.0	150.3	173.4	.....	
Dibenzyl sulfide.....	C ₁₄ H ₁₄ S		85.4	116.0	131.4	147.7	165.7	177.0	192.2	215.0	240.0	265.0	.....	
Dibenzyl sulfide.....	C ₁₄ H ₁₄ S		43.0	73.0	87.6	102.7	120.0	130.6	145.3	166.4	191.0	216.0	.....	
Dibenzylamine.....	C ₁₄ H ₁₅ N		118.3	149.8	165.6	182.2	200.2	212.2	227.3	249.8	274.3	300.0	-26	
Dibenzyl ketone (1,3-diphenyl-2-propanone).....	C ₁₅ H ₁₂ O		125.5	159.8	177.6	195.7	216.6	229.4	246.4	272.3	301.7	330.5	34.5	
1,4-Dibromobenzene.....	C ₆ H ₄ Br ₂		61.0	79.3	87.7	103.4	120.8	131.6	146.5	168.3	192.5	218.6	87.5	
1,2-Dibromobutane.....	C ₄ H ₈ Br ₂		7.5	33.2	46.1	60.0	76.0	86.0	99.8	120.2	143.5	166.3	-64.5	
di-2,3-Dibromobutane.....	C ₄ H ₈ Br ₂		+5.0	30.0	41.6	56.4	72.0	82.0	95.3	115.7	138.0	160.9	.....	
meso-2,3-Dibromobutane.....	C ₄ H ₈ Br ₂		+1.5	25.0	39.3	53.2	68.0	78.0	91.7	111.8	134.2	157.3	-34.5	
1,2-Dibromocyclohexane.....	C ₆ H ₁₀ Br ₂		95.7	125.6	137.3	151.0	167.4	177.5	190.2	209.6	229.8	250.4	.....	
Di(2-bromomethyl) ether.....	C ₄ H ₈ Br ₂ O		47.7	75.3	88.5	103.4	119.8	130.0	144.0	165.0	188.0	212.5	.....	
α,β-Dibromomaleic anhydride.....	C ₄ H ₂ Br ₂ O ₃		50.0	78.0	92.0	106.7	125.3	133.8	147.7	168.0	192.0	215.0	.....	
1,2-Dibromo-2-methylpropane.....	C ₄ H ₈ Br ₂		-28.8	-3.0	+10.5	25.7	42.3	53.7	68.8	92.1	119.8	149.0	-70.3	
1,3-Dibromo-2-methylpropane.....	C ₄ H ₈ Br ₂		14.0	40.0	53.0	67.3	83.5	93.7	107.4	127.8	150.4	174.6	.....	
1,2-Dibromopentane.....	C ₅ H ₁₀ Br ₂		19.8	45.4	58.0	72.0	87.4	97.4	110.1	130.2	151.8	175.0	.....	
1,2-Dibromopentane.....	C ₅ H ₁₀ Br ₂		-7.0	+17.3	29.4	42.3	57.2	66.4	79.7	97.8	118.5	141.4	-55.5	
1,3-Dibromopentane.....	C ₅ H ₁₀ Br ₂		+9.7	35.4	48.0	62.1	77.0	87.8	101.3	121.7	144.1	167.5	-34.4	
2,3-Dibromopentane.....	C ₅ H ₁₀ Br ₂		-6.0	+17.9	30.0	43.2	57.6	67.0	79.5	98.0	119.5	141.2	.....	
2,3-Dibromo-1-propanol.....	C ₃ H ₆ Br ₂ O		57.0	84.5	98.2	113.5	129.8	140.0	153.0	173.8	196.0	219.0	.....	
Dibutylamine.....	C ₈ H ₁₈ N		-5.1	+18.4	30.6	45.7	60.0	67.0	79.2	97.4	118.0	139.5	-30	
2,6-Di-tert-butyl-4-cresol.....	C ₁₄ H ₂₀ O		85.8	116.2	131.0	147.0	164.1	175.2	190.0	212.8	237.6	262.5	.....	
4,6-Di-tert-butyl-2-cresol.....	C ₁₄ H ₂₀ O		86.2	117.5	132.4	149.0	167.4	179.0	194.0	217.5	243.4	269.3	.....	
4,6-Di-tert-butyl-3-cresol.....	C ₁₄ H ₂₀ O		103.7	135.2	150.0	167.0	185.3	196.1	211.0	233.0	257.1	282.0	.....	
2,6-Di-tert-butyl-4-ethylphenol.....	C ₁₆ H ₂₂ O		89.1	121.4	137.0	154.0	172.1	183.9	198.0	220.0	244.0	268.0	.....	
4,6-Di-tert-butyl-3-ethylphenol.....	C ₁₆ H ₂₂ O		111.5	142.6	157.4	174.0	192.3	204.4	218.0	241.7	264.4	289.0	.....	
Dibutyl sulfide.....	C ₈ H ₁₈ S		63.2	91.2	105.3	120.3	137.5	147.8	161.8	183.5	205.4	228.5	.....	
2,4-Di-tert-butylphenol.....	C ₁₄ H ₂₀ O		84.5	115.4	130.0	146.0	164.3	175.8	190.0	212.5	237.0	262.0	.....	
Dibutyl phthalate.....	C ₁₆ H ₂₂ O ₄		148.2	182.1	198.2	216.2	235.8	247.8	263.7	287.0	313.5	340.0	.....	
sulfide.....	C ₈ H ₁₈ S		+17.7	51.8	66.4	80.9	96.0	105.8	118.6	138.0	159.0	182.0	-79.7	
Diisobutyl d-tartrate.....	C ₁₂ H ₂₀ O ₆		117.8	151.8	169.0	188.0	208.5	221.6	239.5	264.7	294.0	324.0	73.5	
Dicarbonyl mono-(6-chloro-2-vinyl) phosphite.....	C ₆ H ₈ ClO ₂ P		204.2	234.5	249.3	264.5	280.5	290.7	304.9	323.8	342.0	361.0	.....	
Dicarbonyl-2-ethyl phosphite.....	C ₆ H ₈ O ₂ P		160.2	209.3	221.8	237.0	251.5	260.3	272.5	290.0	309.8	330.0	.....	
Dichloroacetic acid.....	C ₂ H ₂ Cl ₂ O ₂		44.0	69.8	82.6	96.3	111.8	121.5	134.0	152.3	173.7	194.4	9.7	
1,2-Dichlorobenzene.....	C ₆ H ₄ Cl ₂		20.0	46.0	59.1	73.4	89.4	99.5	112.9	133.4	155.8	179.0	-17.6	
1,3-Dichlorobenzene.....	C _{6</}													

Compound		Pressure, mm. Hg										Melting point, °C.
Name	Formula	1	5	10	20	40	60	100	200	400	760	
Temperature, °C.												
Di(2-chloroethyl) ether.....	C ₄ H ₈ Cl ₂ O	23.5	49.3	62.0	76.0	91.5	101.5	114.5	134.0	155.4	178.5	
Dichlorodifluoromethane.....	CHClF ₂	-91.3	-75.5	-67.5	-58.6	-48.8	-42.6	-35.9	-20.9	-6.2	+4.9	-135
1,5-Dichlorohexamethylene.....	C ₆ H ₁₀ Cl ₂ O ₂	26.0	52.0	65.1	79.0	94.8	105.0	118.2	134.3	160.2	184.0	-33.0
Dichloromethylphenylsilane.....	C ₆ H ₅ CH ₂ SiCl ₂	35.7	63.5	77.4	92.4	109.5	120.0	134.2	155.5	180.2	205.5	
1,1-Dichloro-2-methylpropane.....	C ₄ H ₈ Cl ₂	-31.0	-8.4	+2.6	14.6	28.2	37.0	48.2	65.8	85.4	106.0	
1,2-Dichloro-2-methylpropane.....	C ₄ H ₈ Cl ₂	-25.8	-4.2	+4.7	18.7	32.0	40.2	51.7	68.9	87.4	108.0	
1,3-Dichloro-2-methylpropane.....	C ₄ H ₈ Cl ₂	-3.0	+20.6	32.0	44.8	58.6	67.5	78.8	96.1	115.4	135.0	
2,4-Dichlorophenol.....	C ₆ H ₄ Cl ₂ O	53.0	80.0	92.8	107.7	123.4	135.5	146.0	165.2	187.5	210.0	45.0
2,6-Dichlorophenol.....	C ₆ H ₄ Cl ₂ O	59.5	87.6	101.0	115.5	131.6	141.8	154.6	175.2	197.7	220.5	
2,4-Dichlorophenylamine.....	C ₆ H ₃ Cl ₂ N	56.0	84.0	98.1	113.0	130.0	141.0	154.5	176.2	199.5	223.5	
2,6-Dichlorophenylamine.....	C ₆ H ₃ Cl ₂ N	61.8	100.0	116.0	133.1	151.0	163.2	178.9	202.8	228.0	254.5	
Dichlorophenylamine.....	C ₆ H ₅ Cl ₂ N	-38.5	-17.0	-4.1	+4.0	19.4	28.0	39.4	57.0	76.0	96.8	
1,2-Dichloropropane.....	C ₃ H ₆ Cl ₂	61.0	90.1	104.6	120.5	137.8	149.0	163.5	185.7	210.0	235.0	
2,3-Dichloropropane.....	C ₃ H ₆ Cl ₂	53.5	82.2	97.4	111.8	129.2	140.0	153.8	176.0	200.0	225.0	
2,4-Dichloropropane.....	C ₃ H ₆ Cl ₂	55.5	83.9	98.2	114.0	131.0	142.0	155.8	178.0	202.5	227.0	
2,6-Dichloropropane.....	C ₃ H ₆ Cl ₂	47.8	75.7	90.0	105.5	122.4	133.3	147.6	169.0	193.5	217.0	
3,4-Dichloropropane.....	C ₃ H ₆ Cl ₂	57.2	86.0	100.4	116.2	133.7	144.6	158.2	181.5	205.7	230.0	
3,5-Dichloropropane.....	C ₃ H ₆ Cl ₂	53.5	82.2	97.4	111.8	129.2	140.0	153.8	176.0	200.0	225.0	
1,2-Dichlorotetraethylsilane.....	C ₈ H ₁₈ Cl ₂ Si	105.6	158.7	155.0	172.5	192.2	204.8	220.7	245.4	272.8	302.0	
1,4-Dichlorotetraethylsilane.....	C ₈ H ₁₈ Cl ₂ Si	91.7	125.1	143.8	162.0	183.2	195.8	212.0	234.5	265.8	296.5	
1,2-Dichloro-1,1,2,2-tetrafluoroethane.....	C ₂ Cl ₂ F ₄	-35.4	-30.0	-22.3	-13.7	-7.7	-4.5	-39.1	-26.3	-12.0	+3.5	-94
Dichloro-4-ethylsilane.....	C ₆ H ₁₃ Cl ₂ Si	46.2	71.7	84.2	97.0	113.2	122.4	135.5	153.5	175.2	196.5	
3,4-Dichloro-2,2,4,4-tetrafluorobutane.....	C ₄ Cl ₂ F ₆	11.0	34.3	52.2	67.3	84.0	95.0	109.2	129.0	150.5	172.8	-12.1
Dichlorodimethylsilane.....	C ₂ H ₆ Cl ₂ Si	-19.1	+2.4	13.3	25.3	38.0	46.3	57.4	74.2	92.2	113.5	32.9
Dichlorodiphenylsilane.....	C ₁₂ H ₁₀ Cl ₂ Si	111.5	142.8	157.6	174.3	193.2	205.0	220.0	243.8	270.7	296.0	
Diethyl adipate.....	C ₁₀ H ₁₈ O ₄	74.0	106.6	123.0	138.3	154.6	165.8	179.0	198.2	219.1	240.0	-21
Diethylamine.....	C ₄ H ₁₁ N	-49.7	78.0	91.9	107.2	125.6	133.8	147.3	168.2	192.4	215.5	-34.4
N-Diethylamine.....	C ₄ H ₁₁ N	38.0	62.6	74.8	88.0	102.6	111.8	123.8	141.9	161.0	181.0	
Diethyl arsenate.....	C ₄ H ₁₀ AsO ₃	22.3	48.7	62.0	76.4	92.5	102.6	116.2	136.7	159.0	185.5	-31.4
1,3-Diethylbenzene.....	C ₈ H ₁₀	20.7	46.8	59.9	74.5	90.4	100.7	114.4	134.8	156.9	181.1	-43.9
1,4-Diethylbenzene.....	C ₈ H ₁₀	20.7	47.1	60.3	74.7	91.1	101.3	115.5	136.1	159.0	183.8	-43.2
Diethyl carbonate.....	C ₆ H ₁₂ O ₃	-10.1	+12.3	23.8	36.0	49.5	57.9	69.7	86.5	105.8	125.8	-43
Diethyl citraconate.....	C ₁₀ H ₁₈ O ₄	59.8	88.3	103.0	118.2	135.7	146.2	160.0	183.3	206.5	230.5	
Diethyl diisocrotonate.....	C ₁₀ H ₁₈ O ₄	70.0	98.0	112.0	126.8	143.8	153.7	167.7	188.0	210.6	233.5	
Diethyl glycol.....	C ₆ H ₁₂ O ₃	91.8	120.0	133.8	148.0	164.3	174.0	187.5	207.0	226.5	244.8	
Diethyl glycol dimethyl ether Di(2-methoxyethyl) ether.....	C ₆ H ₁₄ O ₂	148.3	180.0	195.8	212.0	229.0	239.5	252.0	271.5	291.8	313.0	
Diethyl glycol ether.....	C ₆ H ₁₂ O ₂	13.0	37.6	50.0	63.0	77.5	86.8	99.5	118.0	138.5	159.8	
Diethyl ether.....	C ₄ H ₁₀ O	45.3	72.0	85.0	100.5	116.7	126.8	140.3	159.0	180.3	201.9	
Diethyl malonate.....	C ₆ H ₁₀ O ₄	-74.3	-56.9	-48.1	-38.5	-27.7	-21.8	-11.5	+2.2	17.9	34.4	-116.3
Diethyl succinate.....	C ₆ H ₁₀ O ₄	50.8	77.8	91.4	106.0	122.4	132.4	146.0	166.0	188.7	211.5	
Diethyl glutarate.....	C ₈ H ₁₄ O ₄	53.2	81.2	95.3	110.2	125.7	137.7	151.1	172.2	195.8	218.5	+0.6
Diethyl hexadecylamine.....	C ₁₈ H ₃₇ N	65.6	94.7	109.7	125.4	142.6	153.2	167.8	189.5	212.8	237.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	139.8	175.8	194.0	213.5	235.0	248.5	265.5	292.8	324.6	355.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	51.3	80.2	95.2	110.0	125.2	139.9	154.3	177.5	203.1	227.9	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-12.7	+7.5	17.2	27.9	39.4	46.7	56.2	70.6	86.3	102.7	-42
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	80.7	110.4	125.3	141.2	157.8	169.0	183.9	205.3	229.5	253.4	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	57.3	85.6	100.0	115.3	131.8	142.4	156.0	177.8	201.7	225.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	40.0	67.5	81.3	95.9	113.3	123.0	136.2	155.5	176.8	198.9	-49.8
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	62.8	91.0	105.3	120.3	137.3	147.9	161.6	183.2	205.8	229.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	47.4	71.8	85.8	100.6	116.7	119.7	130.8	147.9	166.2	185.7	-40.6
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	108.8	140.7	156.0	173.6	192.1	204.1	219.5	243.0	267.5	294.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	125.3	156.2	172.1	189.8	207.5	218.4	234.4	255.8	280.3	305.5	1.3
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	49.7	78.4	92.6	108.5	125.8	136.6	151.0	173.2	198.0	223.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	54.6	83.0	96.6	111.7	127.8	138.2	151.1	171.7	193.8	216.5	-20.8
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	39.8	66.7	80.0	94.7	111.0	121.4	134.8	155.1	177.7	201.3	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	47.0	74.0	87.7	102.1	118.0	128.6	142.5	162.5	185.5	209.5	-25.0
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-39.6	-18.6	-8.0	+3.5	16.1	24.2	35.0	49.7	68.0	88.0	-99.5
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	102.0	133.0	148.0	164.2	182.3	194.0	208.5	230.4	254.8	280.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	100.0	131.7	147.2	163.8	181.7	193.2	208.0	230.0	254.3	280.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	34.0	61.5	75.3	90.2	107.0	117.7	131.7	152.4	176.5	200.7	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-22.4	0.0	+11.7	24.2	38.0	47.2	59.1	77.0	97.3	118.0	-28
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	46.6	75.5	90.0	106.0	123.7	134.7	149.7	171.8	197.0	223.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	68.0	91.7	103.0	115.0	127.6	136.7	145.9	160.2	176.8	193.5	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	196.7	239.8	259.8	282.0	307.4	323.3	344.3	377.8	413.0	450.0	194
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-73.0	-57.9	-50.5	-42.5	-33.9	-27.8	-18.8	-5.0	+10.6	27.2	-32.5
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-87.7	-72.2	-64.6	-56.0	-46.7	-40.7	-32.6	-20.4	-7.1	+7.4	-96
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	29.5	56.3	70.0	84.8	101.6	111.9	125.8	146.5	169.2	193.1	+2.5
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	15.0	39.6	51.8	65.0	79.7	88.6	101.0	119.8	140.3	160.5	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	96.7	128.3	144.0	160.5	179.6	191.5	206.8	229.7	254.8	281.0	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-69.3	-50.7	-41.5	-31.1	-19.5	-12.1	-2.0	+13.4	31.0	47.7	-99.8
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-63.6	-44.5	-34.9	-24.1	-12.4	-4.9	+3.4	21.1	39.0	58.0	-128.2
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	50.8	78.2	91.8	106.5	122.6	132.7	145.8	165.8	188.0	210.5	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-24.4	-1.4	+10.3	23.0	37.3	45.7	57.9	76.2	97.2	119.5	-34
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-15.9	+7.3	18.4	31.1	45.3	54.4	66.8	85.6	107.0	129.7	-50.0
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-21.1	+1.7	13.0	25.6	39.7	48.7	61.0	79.6	100.9	123.4	-88.0
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-19.4	+3.4	14.9	27.4	41.4	50.4	62.5	81.0	102.1	124.4	-92.0
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-22.7	0.0	+11.2	23.6	37.5	46.4	58.5	76.9	97.6	120.1	-76.2
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-20.0	+3.2	14.5	27.1	41.1	50.1	62.3	80.8	101.9	124.3	-87.4
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-24.3	-1.7	+10.1	22.6	36.5	45.4	57.6	76.0	97.0	119.3	-36.9
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-115.7	-101.1	-93.3	-85.2	-76.2	-70.4	-62.7	-50.9	-37.6	-22.7	-130.5
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-29.7	-7.9	+3.1	15.0	28.2	36.7	46.2	65.7	85.6	106.8	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-23.0	-1.1	+9.9	22.1	35.6	44.2	56.0	73.8	94.1	115.6	
Diethyl itaconate.....	C ₈ H ₁₄ O ₄	-26.9	-5.3</									

Compound	Name	Formula	Pressure, mm. Hg										Melting point, °C.
			1	5	10	20	40	60	100	200	400	760	
			Temperature °C.										
1,1-Dimethylbenzene		C ₈ H ₁₀	-25.0	-4.4	+6.1	18.2	31.7	40.4	52.5	70.0	90.0	112.0	
1,4-Dimethylbenzene		C ₈ H ₁₀	-22.1	+4.2	11.3	23.5	37.1	45.8	57.7	75.0	96.0	117.0	
Dimethyl itaconate		C ₈ H ₁₀ O ₄	69.3	94.0	106.6	119.7	133.7	142.6	153.7	171.0	189.0	224.0	38
1-Dimethyl malate		C ₈ H ₁₀ O ₄	73.4	104.0	118.3	133.8	150.1	160.4	175.1	196.3	219.9	242.0	
Dimethyl malonate		C ₈ H ₁₀ O ₄	45.7	73.0	88.4	101.3	117.2	127.1	140.4	160.0	182.2	205.0	
trans-Dimethyl succinate		C ₈ H ₁₀ O ₄	46.8	74.0	87.9	101.0	117.0	127.1	140.4	160.0	182.2	205.0	
2,7-Dimethylcyclohexane		C ₈ H ₁₆	+6.3	30.3	42.3	56.0	69.4	82.0	94.0	106.0	118.0	130.0	-63
Dimethyl oxalate		C ₈ H ₁₀ O ₄	20.0	44.0	56.0	69.4	82.0	94.0	106.0	118.0	130.0	142.0	-52.0
2,3-Dimethylpentane		C ₇ H ₁₆	-49.0	-23.7	-18.7	-7.5	+3.9	12.5	21.1	29.7	38.3	46.9	-123.7
2,4-Dimethylpentane		C ₇ H ₁₆	-42.0	-20.8	-10.3	+1.1	13.9	22.5	31.1	39.7	48.3	56.9	-135
3,3-Dimethylpentane		C ₇ H ₁₆	-48.0	-27.4	-17.1	-5.9	+4.5	13.1	21.7	30.3	38.9	47.5	-119.5
2,3-Dimethylphenol (2,3-cyclohexadienol)		C ₇ H ₈ O	-45.9	-25.0	-14.4	-2.9	+9.9	18.5	27.1	35.7	44.3	52.9	-135.0
2,4-Dimethylphenol (2,4-cyclohexadienol)		C ₇ H ₈ O	56.0	83.0	97.6	112.0	126.4	139.9	152.2	173.0	194.0	215.0	
2,5-Dimethylphenol (2,5-cyclohexadienol)		C ₇ H ₈ O	51.8	78.0	91.3	105.0	121.2	131.0	143.0	161.0	184.0	211.0	
3,4-Dimethylphenol (3,4-cyclohexadienol)		C ₇ H ₈ O	51.8	78.0	91.3	105.0	121.2	131.0	143.0	161.0	184.0	211.0	
3,5-Dimethylphenol (3,5-cyclohexadienol)		C ₇ H ₈ O	66.2	93.0	107.7	122.0	138.0	148.0	161.0	181.0	203.0	225.0	
Dimethylphenylsilane		C ₇ H ₁₀ Si	+5.3	30.3	42.3	56.0	69.4	82.0	94.0	106.0	118.0	130.0	
Dimethyl phtalate		C ₇ H ₈ O ₄	100.3	131.0	147.0	164.0	182.0	194.0	210.0	232.0	257.0	283.0	
3,5-Dimethyl-1,2-pyrazole		C ₇ H ₈ N ₂	78.0	107.0	122.0	138.0	152.0	163.0	177.0	198.0	219.0	240.0	31.5
4,6-Dimethylpyrimidine		C ₇ H ₈ N ₂	49.0	76.0	90.7	103.0	122.0	135.0	147.0	167.0	192.0	215.0	
Dimethyl sebacate		C ₇ H ₁₄ O ₄	104.0	139.0	156.2	173.0	196.0	208.0	222.0	245.0	269.0	293.0	38
2,4-Dimethylstyrene		C ₇ H ₈	34.2	61.9	73.6	90.8	107.7	118.0	132.0	153.0	177.0	202.0	
cis-Dimethylsuccinimide anhydride		C ₇ H ₁₀ N ₂ O ₂	29.0	55.9	69.0	84.0	100.2	110.7	124.7	145.0	168.0	193.0	
Dimethyl sulfoxide		C ₇ H ₈ S	61.4	88.1	102.0	116.3	132.3	142.4	153.3	173.0	197.0	219.0	
d-Dimethyl tartrate		C ₇ H ₁₀ O ₆	-75.6	-58.0	-49.2	-39.4	-28.4	-21.4	-12.0	+2.0	18.7	36.0	-83.2
d-Dimethyl tartrate		C ₇ H ₁₀ O ₆	102.1	133.2	148.2	164.3	182.4	193.8	208.0	230.0	253.0	280.0	61.5
N,N-Dimethyl-2-toluidine		C ₇ H ₁₀ N ₂	100.4	131.0	147.0	164.0	182.0	194.0	210.0	232.0	257.0	283.0	
N,N-Dimethyl-4-toluidine		C ₇ H ₁₀ N ₂	23.8	54.1	66.2	80.2	95.0	105.2	118.1	138.3	161.5	184.8	
Di(nitrosomethyl) amine		C ₇ H ₁₀ N ₂ O ₂	+3.2	27.4	40.0	53.7	68.2	77.7	90.3	110.0	131.3	153.0	
Diphenol		C ₇ H ₈ O ₂	66.7	93.0	109.0	124.0	141.2	151.3	165.6	186.2	209.5	232.0	
1,4-Dioxane		C ₆ H ₁₀ O	-35.0	-12.8	10.0	24.0	38.0	45.1	62.5	81.0	101.1	121.0	10
Dipentene		C ₆ H ₁₀	14.0	40.4	53.0	68.2	82.0	94.0	106.0	118.0	130.0	142.0	
Diphenylamine		C ₆ H ₁₀ N	108.3	141.7	157.0	173.2	194.3	206.9	222.8	247.3	274.1	302.0	52.9
Diphenyl carbene (diphenylidene)		C ₆ H ₁₀	110.0	145.0	162.0	180.9	200.0	212.0	227.3	250.0	275.0	301.0	68.5
chlorophenol		C ₆ H ₅ ClO	121.5	160.5	182.0	203.8	227.9	244.2	261.3	289.3	317.0	345.0	
1,2-Diphenylbenzene (dibenzylidene)		C ₆ H ₁₀	131.6	164.0	180.0	197.0	214.3	226.2	241.3	262.6	285.0	310.0	61
Diphenyl ether		C ₆ H ₁₀ O	86.8	119.8	136.0	153.7	173.7	186.0	202.8	227.0	253.0	284.0	51.5
1,1-Diphenylethylene		C ₆ H ₁₀	66.1	97.8	114.0	130.3	150.0	162.0	178.0	203.3	228.7	253.0	27
trans-Diphenylethylene		C ₆ H ₁₀	87.4	119.6	135.0	151.8	170.8	183.6	198.6	222.8	249.6	275.0	
1,1-Diphenylhydrazine		C ₆ H ₁₀ N ₂	115.2	145.8	161.0	179.8	199.0	211.5	227.4	251.7	278.3	306.4	124
Diphenylmethane		C ₆ H ₁₀	126.0	157.3	172.3	194.0	213.5	225.9	242.5	267.2	294.0	322.2	44
Diphenyl sulfide		C ₆ H ₁₀ S	76.0	107.4	122.3	139.8	157.8	170.2	186.3	210.7	237.5	264.5	26.5
Diphenyl-2-ethyl thiophosphate		C ₆ H ₁₀ O ₂ P	96.1	129.0	145.0	162.0	182.0	194.0	211.0	236.0	263.0	292.0	
1,2-Dipropoxyethane		C ₆ H ₁₄ O ₂	159.7	177.8	201.6	215.5	230.6	240.4	252.9	270.3	290.0	310.0	
1,3-Diisopropylbenzene		C ₆ H ₁₀	-38.0	-10.3	+5.0	22.3	42.3	55.8	74.2	103.8	140.0	180.0	
1,3-Diisopropylbenzene		C ₆ H ₁₀	40.0	67.8	81.8	96.8	114.0	124.3	138.7	158.9	184.3	209.0	
Dipropylene glycol		C ₆ H ₁₀ O ₂	34.7	62.3	76.0	91.2	107.0	118.2	132.3	153.7	177.6	202.0	-105
Dipropylene glycol monomethyl ether		C ₆ H ₁₀ O ₂	73.8	102.1	116.2	131.3	147.4	156.3	169.9	189.9	210.5	231.8	
isopropyl ether		C ₆ H ₁₀ O	64.7	92.0	106.0	120.4	136.3	146.3	159.8	180.0	203.8	227.0	
Di-n-propyl ether		C ₆ H ₁₀ O	46.0	72.8	86.2	100.8	117.0	126.8	140.3	160.0	183.1	205.6	
Di-n-propyl ether		C ₆ H ₁₀ O	-43.3	-22.3	-11.8	0.0	+13.2	21.6	33.0	50.3	69.5	89.2	-122
Di-n-propyl ketone (4-heptanone)		C ₆ H ₁₀ O	-57.0	-37.4	-27.4	-16.7	-4.5	+3.4	13.7	30.0	48.2	67.5	-60
Di-n-propyl oxalate		C ₆ H ₁₀ O ₄	23.0	44.4	55.0	66.2	78.1	83.8	96.0	111.2	127.3	143.7	-32.6
Diisopropyl oxalate		C ₆ H ₁₀ O ₄	33.4	60.2	73.9	88.6	103.6	124.6	134.8	148.1	168.0	190.3	
Di-n-propyl succinate		C ₆ H ₁₀ O ₄	77.5	107.6	122.2	138.0	154.8	166.0	180.3	202.5	226.5	250.8	
Di-n-propyl d-tartrate		C ₆ H ₁₀ O ₆	115.6	147.7	163.5	180.4	199.7	211.7	227.0	250.1	275.0	300.0	
Diradyl acetylene (1,5-hexadiene-3-yne)		C ₆ H ₆	103.7	133.7	148.2	164.2	181.8	192.6	207.3	228.2	251.8	275.0	
1,3-Divinylbenzene		C ₆ H ₆	-45.1	-24.4	-14.0	-2.6	+10.0	18.1	29.5	46.0	64.0	84.0	
Dodecane		C ₆ H ₁₄	32.7	60.0	73.8	88.7	103.5	116.0	130.0	151.4	175.2	199.5	-66.9
n-Dodecane		C ₆ H ₁₄	157.8	193.4	213.0	233.5	254.3	268.3	286.0	314.2	343.5	376.0	44.5
1-Dodecene		C ₆ H ₁₂	47.8	75.8	90.0	104.6	121.7	132.1	146.2	167.2	191.0	216.2	-9.6
n-Dodecyl alcohol		C ₆ H ₁₄ O	47.2	74.0	87.8	102.4	118.6	128.5	142.3	162.2	185.5	208.0	-31.5
Dodecyltrimethylsilane		C ₆ H ₁₄ Si	91.0	120.2	134.7	150.0	167.2	177.3	192.0	213.0	235.7	259.0	24
Dodecyltrimethylsilane		C ₆ H ₁₄ Si	82.8	111.8	127.8	141.6	157.4	168.0	182.1	203.0	225.0	248.0	
Elaidic acid		C ₆ H ₁₀ O ₂	91.2	122.1	137.7	153.8	172.1	184.2	199.5	222.0	244.0	267.0	
Epichlorohydrin		C ₆ H ₁₀ ClO	171.3	226.7	223.5	242.3	260.8	273.0	288.0	312.4	337.0	362.0	51.5
1,2-Epoxy-2-methylpropane		C ₆ H ₁₀ O	-16.3	+5.6	16.6	29.0	42.0	50.6	62.0	79.3	94.0	117.9	-25.6
Eroic acid		C ₆ H ₁₀ O ₂	-69.0	-50.0	-40.3	-29.5	-17.3	-9.7	+1.2	17.5	36.0	55.5	
Estroic acid (p-methoxy allyl benzoate)		C ₆ H ₁₀ O ₂	206.7	239.7	254.5	270.6	289.1	300.2	314.4	336.5	358.8	381.5	33.5
Ethane		C ₆ H ₁₄	52.0	80.0	93.7	108.4	124.6	135.2	148.5	168.7	192.0	215.0	
Ethoxydimethylphenylsilane		C ₆ H ₁₀ OSi	-159.5	-148.5	-142.9	-136.7	-129.8	-125.4	-119.3	-110.2	-99.7	-88.6	-183.2
Ethoxytrimethylsilane		C ₆ H ₁₀ OSi	36.3	63.1	76.2	91.0	107.2	127.5	131.4	151.5	175.0	199.5	
Ethoxytriphenylsilane		C ₆ H ₁₀ OSi	-50.9	-31.0	-23.7	-9.8	+5.7	11.5	22.1	38.1	56.3	75.7	
Ethyl acetate		C ₆ H ₁₀ O ₂	167.0	198.2	213.5	230.0	247.0	258.3	273.3	295.0	319.5	344.0	
acetone		C ₆ H ₁₀ O	-43.4	-23.5	-13.5	-3.0	+9.1	16.6	27.0	42.0	59.3	77.1	-82.4
Ethylacrylate (1-butene)		C ₆ H ₁₀ O ₂	23.5	54.0	67.3	81.1	96.2	106.0	118.5	138.0	158.2	180.0	-45
Ethyl acrylate		C ₆ H ₁₀ O ₂	-92.5	-76.7	-60.7	-59.9	-50.0	-43.4	-34.9	-21.6	-6.9	+8.7	-130
c-Ethylacrylic acid		C ₆ H ₁₀ O ₂	-29.5	-8.7	+2.0	13.0	26.0	33.5	44.5	61.0	80.0	99.5	-71.2
c-Ethylacrylonitrile		C ₆ H ₁₀ N	47.0	70.7	82.0	94.4	103.1	116.7	127.5	144.0	160.7	178.2	
Ethyl alcohol (ethanol)		C ₆ H ₁₀ O	-29.0	-6.4	+5.0	17.7	31.8	40.6	53.0	71.6	92.2	114.0	
Ethylamine		C ₆ H ₁₀ N	-31.3	-12.0	-2.3	+8.0	19.0	28.0	34.9	44.4	63.3	83.0	-112
4-Ethylaniline		C ₆ H ₁₀ N	-82.3	-66.4	-53.3	-44.6	-39.8	-33.4	-25.1	-12.3	+2.0	16.4	-90.6
N-E													

Compound	Name	Formula	Pressure, mm. Hg										Mol. wt.	Boiling point, °C.
			Temperature, °C.											
			1	5	10	20	40	60	100	200	400	760		
2-Ethylhexanol	2-Ethylhexanol	C ₈ H ₁₈ O	29.7	55.9	69.0	83.1	98.0	109.0	122.3	142.1	164.2	187.1		
3-Ethylhexanol	3-Ethylhexanol	C ₈ H ₁₈ O	33.7	60.3	73.9	88.3	104.8	115.3	129.2	149.7	172.8	196.5		
4-Ethylhexanol	4-Ethylhexanol	C ₈ H ₁₈ O	33.5	60.2	73.9	88.3	104.7	115.4	129.4	149.8	172.9	196.6		
Ethyl hexanoate	Ethyl hexanoate	C ₈ H ₁₆ O ₂	-9.6	+13.9	25.9	38.6	52.8	61.8	74.1	92.7	113.8	136.2	-44.9	
Ethyl hexanoate	Ethyl hexanoate	C ₈ H ₁₆ O ₂	44.0	72.0	86.0	101.4	118.2	129.0	143.2	164.8	188.4	213.4	-34.6	
benzyl hexanoate	benzyl hexanoate	C ₁₂ H ₂₂ O ₂	107.6	136.4	150.3	166.8	181.0	191.9	205.0	223.8	244.7	265.0		
hexanoic acid	hexanoic acid	C ₆ H ₁₂ O ₂	-74.3	-56.4	-47.5	-37.8	-26.7	-19.5	-10.0	+4.5	21.0	38.4	-117.8	
n-butyl hexanoate	n-butyl hexanoate	C ₁₀ H ₂₀ O ₂	10.6	35.8	48.0	61.8	77.0	86.7	99.8	119.7	141.2	163.6		
n-butyl hexanoate	n-butyl hexanoate	C ₁₀ H ₂₀ O ₂	-18.4	+4.0	15.3	27.8	41.3	50.1	62.0	79.0	100.0	121.0	-95.3	
isobutyl hexanoate	isobutyl hexanoate	C ₁₀ H ₂₀ O ₂	-24.3	-2.4	+8.4	20.6	33.8	42.3	53.5	71.0	90.0	110.0	-88.2	
Ethyl hexanoate	Ethyl hexanoate	C ₈ H ₁₆ O ₂	118.2	149.8	165.0	181.8	199.8	211.5	226.6	246.5	272.8	298.0		
Ethyl isocaproate	Ethyl isocaproate	C ₈ H ₁₆ O ₂	11.0	35.8	48.0	61.7	76.3	85.8	98.4	117.8	139.2	160.4		
carbamate	carbamate	C ₈ H ₁₅ NO ₂		65.8	77.8	91.0	105.6	114.8	126.2	145.2	164.0	184.0	49	
carbamate	carbamate	C ₈ H ₁₅ NO ₂	107.8	131.8	143.7	155.5	168.8	177.3	187.9	203.8	220.0	237.0	52.5	
Ethyl hexylamine	Ethyl hexylamine	C ₈ H ₁₇ N	133.2	168.2	186.0	205.3	226.5	239.8	256.8	283.3	313.0	342.0		
Ethyl chloride	Ethyl chloride	C ₂ H ₅ Cl	-89.6	-73.9	-65.6	-56.8	-47.0	-40.6	-32.0	-18.6	-3.9	+12.3	-139	
chloroacetate	chloroacetate	C ₂ H ₄ ClO ₂	+1.0	25.4	37.5	50.4	62.2	74.0	86.0	103.8	123.8	144.2	-26	
chloroacrylate	chloroacrylate	C ₃ H ₃ ClO ₂	-5.1	+18.0	29.9	42.0	54.0	65.2	76.6	94.5	114.7	135.0		
α-chloropropionate	α-chloropropionate	C ₃ H ₅ ClO ₂	+6.6	30.2	41.9	54.3	66.2	77.3	89.3	107.2	126.2	146.5		
trans-cinnamate	trans-cinnamate	C ₉ H ₇ O ₂	87.6	108.5	134.0	150.3	169.2	181.2	196.0	219.3	245.0	271.0	12	
3-Ethylhexanol	3-Ethylhexanol	C ₈ H ₁₈ O	29.3	55.5	68.8	83.6	99.9	110.2	124.3	145.4	168.2	193.0		
4-Ethylhexanol	4-Ethylhexanol	C ₈ H ₁₈ O	31.5	58.4	72.0	86.7	103.3	113.8	127.3	148.3	171.8	195.8		
Ethyl cyclohexanecarboxylate	Ethyl cyclohexanecarboxylate	C ₈ H ₁₆ O ₂	47.8	93.5	106.0	119.8	133.8	142.1	152.8	169.8	187.8	206.0		
Ethyl cyclohexanecarboxylate	Ethyl cyclohexanecarboxylate	C ₈ H ₁₆ O ₂	-14.5	+9.2	20.6	33.4	47.6	56.7	69.0	87.8	109.1	131.8	-111.3	
Ethyl cyclohexanecarboxylate	Ethyl cyclohexanecarboxylate	C ₈ H ₁₆ O ₂	-32.2	-10.8	-0.1	+11.7	25.0	33.4	45.0	62.4	82.3	103.4	-138.6	
Ethyl dichloroacetate	Ethyl dichloroacetate	C ₂ H ₃ Cl ₂ O ₂	9.6	34.0	46.3	59.5	74.0	83.6	96.1	115.2	135.9	156.5		
N,N-diethylhexanamine	N,N-diethylhexanamine	C ₁₀ H ₂₂ N	76.0	106.3	121.7	137.7	154.4	166.0	180.3	202.8	226.5	252.0		
N-Ethylhexanamine	N-Ethylhexanamine	C ₈ H ₁₇ N	98.3	130.2	146.0	162.8	182.0	193.7	209.8	233.0	258.8	286.0		
Ethylene	Ethylene	C ₂ H ₄	-168.3	-158.3	-153.2	-147.6	-141.3	-137.3	-131.8	-123.4	-113.9	-103.7	-169	
Ethylene bis(chloroacetate)	Ethylene bis(chloroacetate)	C ₄ H ₆ Cl ₂ O ₄	112.0	142.4	158.0	173.5	191.0	201.8	215.0	237.3	259.5	283.5		
Ethylene chlorohydrate (2-chloroethanol)	Ethylene chlorohydrate (2-chloroethanol)	C ₂ H ₄ ClO	-4.0	+19.0	30.3	42.5	56.0	64.1	75.0	91.8	110.0	128.8	-69	
diamine (1,2-ethanediamine)	diamine (1,2-ethanediamine)	C ₂ H ₆ N ₂	-11.0	+10.5	21.5	33.0	45.8	55.8	62.5	81.0	99.0	117.2	8.5	
dibromide (1,2-dibromoethane)	dibromide (1,2-dibromoethane)	C ₂ H ₄ Br ₂	-27.0	+4.7	18.6	32.7	48.0	57.9	70.4	89.8	110.1	131.5	10	
dichloride (1,2-dichloroethane)	dichloride (1,2-dichloroethane)	C ₂ H ₄ Cl ₂	-44.5	-24.0	-13.6	-2.4	+10.0	18.1	29.4	45.7	64.0	82.4	-35.3	
glycol (1,2-ethanediol)	glycol (1,2-ethanediol)	C ₂ H ₆ O ₂	53.0	79.7	92.1	105.8	120.0	129.5	141.8	158.5	178.5	197.3	-15.6	
glycol dimethyl ether (2-methoxyethanol)	glycol dimethyl ether (2-methoxyethanol)	C ₃ H ₈ O	-33.5	-10.2	+1.6	14.7	29.7	39.0	51.8	71.8	94.1	119.5		
glycol dimethyl ether (2-methoxyethanol)	glycol dimethyl ether (2-methoxyethanol)	C ₃ H ₈ O	-48.0	-26.2	-15.3	-3.0	+10.7	19.7	31.8	50.0	70.8	93.0		
glycol monomethyl ether (2-methoxyethanol)	glycol monomethyl ether (2-methoxyethanol)	C ₃ H ₈ O	-13.5	+10.2	22.0	34.3	47.8	56.4	68.0	85.3	104.3	124.4		
oxide	oxide	C ₂ H ₄ O	-89.7	-73.8	-65.7	-56.6	-46.9	-40.7	-32.1	-19.5	-4.9	+10.7	-111.3	
Ethyl α-ethylhexanoate	Ethyl α-ethylhexanoate	C ₁₀ H ₂₀ O ₂	40.5	67.3	80.2	94.6	110.3	120.6	133.8	153.2	175.6	198.0		
fluoride	fluoride	C ₂ H ₅ F	-117.0	-103.8	-97.7	-90.0	-81.8	-76.4	-69.3	-58.0	-45.5	-32.0	-79	
formate	formate	C ₂ H ₄ O ₂	-60.5	-42.2	-33.0	-22.7	-11.5	-4.3	-5.4	20.0	37.1	54.3	-79	
2-formate	2-formate	C ₂ H ₄ O ₂	37.6	63.8	77.1	91.5	107.5	117.5	130.4	150.1	172.5	195.0	34	
glyoxalate	glyoxalate	C ₂ H ₂ O ₃	14.3	38.8	50.5	63.9	78.1	87.6	99.8	117.8	138.0	158.2		
1-Ethylhexene	1-Ethylhexene	C ₈ H ₁₆	-20.0	+2.1	12.8	25.0	38.5	47.1	58.9	76.7	97.0	118.0		
2-Ethylhexyl acrylate	2-Ethylhexyl acrylate	C ₁₀ H ₁₈ O ₂	50.0	77.7	91.8	106.3	123.7	134.0	147.9	168.2	192.2	216.0		
Ethylhexene chloride (1,1-dichloroethane)	Ethylhexene chloride (1,1-dichloroethane)	C ₂ H ₃ Cl ₂	-60.7	-41.9	-32.3	-21.9	-10.2	-2.9	+7.2	22.4	39.6	57.4	-96.7	
fluoride (1,1-difluoroethane)	fluoride (1,1-difluoroethane)	C ₂ H ₄ F ₂	-112.5	-98.4	-91.7	-84.1	-75.8	-70.4	-63.2	-52.0	-39.5	-25.5	-117	
Ethyl iodide	Ethyl iodide	C ₂ H ₅ I	-54.4	-34.3	-24.3	-13.1	-0.9	+7.2	18.0	34.1	52.3	72.4	-105	
Ethyl isocinnamate	Ethyl isocinnamate	C ₁₀ H ₁₆ O ₂	27.8	57.3	72.1	88.0	106.0	117.8	131.8	149.8	167.3	184.0		
Ethyl isovalerate	Ethyl isovalerate	C ₈ H ₁₆ O ₂	47.3	74.0	87.3	101.8	117.7	127.6	141.3	160.2	183.0	206.2		
Ethyl isocinnamate	Ethyl isocinnamate	C ₁₀ H ₁₆ O ₂	-76.7	-59.1	-50.2	-40.7	-29.8	-22.4	-13.0	+1.5	17.7	35.0	-121	
Ethyl methylacrylate	Ethyl methylacrylate	C ₅ H ₈ O ₂	26.5	51.0	63.2	76.1	91.0	100.0	112.0	130.0	149.0	170.0		
Ethyl methyl ether	Ethyl methyl ether	C ₃ H ₈ O	-91.0	-75.6	-67.8	-59.1	-49.4	-43.3	-34.8	-22.0	-7.8	+7.5		
1-Ethylmethylacrylate	1-Ethylmethylacrylate	C ₅ H ₈ O ₂	70.0	101.4	116.8	133.8	152.0	164.1	180.0	204.6	230.8	258.1	-27	
Ethyl α-methylacrylate	Ethyl α-methylacrylate	C ₅ H ₈ O ₂	124.0	155.5	171.0	188.1	206.9	218.2	233.5	255.5	280.2	306.0		
Ethyl 3-oxobutanoate	Ethyl 3-oxobutanoate	C ₆ H ₁₀ O ₃	108.1	140.2	155.0	173.6	192.6	205.0	220.3	244.6	270.6	298.0	47	
1-Ethylpentane	1-Ethylpentane	C ₇ H ₁₆	-37.8	-17.0	-6.8	+4.7	17.5	25.7	36.9	53.8	73.0	93.5	-118.6	
2-Ethylpentanol	2-Ethylpentanol	C ₇ H ₁₆ O	48.5	75.7	89.5	103.8	119.8	129.8	143.5	163.2	185.7	208.0		
2-Ethylpentanol	2-Ethylpentanol	C ₇ H ₁₆ O	46.2	73.4	87.0	101.5	117.9	127.9	141.8	161.6	184.5	207.5	-45	
3-Ethylpentanol	3-Ethylpentanol	C ₇ H ₁₆ O	60.0	86.6	100.2	114.5	130.0	139.8	152.0	171.8	193.3	214.0	-4	
4-Ethylpentanol	4-Ethylpentanol	C ₇ H ₁₆ O	59.3	86.5	100.2	115.0	131.3	141.7	154.2	175.0	197.4	219.0	46.5	
Ethyl pentyl ether (pentoxide)	Ethyl pentyl ether (pentoxide)	C ₇ H ₁₆ O	18.1	43.7	56.4	70.3	86.6	95.4	108.4	127.9	149.8	172.0	-30.2	
Ethyl propyl ether	Ethyl propyl ether	C ₅ H ₁₂ O	-28.0	-7.2	+3.4	14.3	27.2	35.1	45.2	61.7	79.8	99.1	-72.6	
Ethyl propyl ether	Ethyl propyl ether	C ₅ H ₁₂ O	-64.3	-45.0	-35.0	-24.0	-12.0	-4.0	+6.8	23.3	41.6	61.7		
Ethyl isopropyl ether	Ethyl isopropyl ether	C ₅ H ₁₂ O	61.2	90.0	104.2	119.3	136.7	147.4	161.5	183.7	207.0	231.5	1.3	
3-Ethylstyrene	3-Ethylstyrene	C ₉ H ₁₀	23.3	55.0	68.3	82.8	99.2	109.6	123.2	144.0	167.2	191.5		
4-Ethylstyrene	4-Ethylstyrene	C ₉ H ₁₀	26.0	52.7	66.3	80.8	97.3	107.6	121.5	142.0	165.0	189.0		
Ethylisothiocyanate	Ethylisothiocyanate	C ₃ H ₄ NS	13.2	+10.6	22.8	36.1	50.8	59.8	71.9	90.0	110.1	131.0	-5.9	
2-Ethyltoluene	2-Ethyltoluene	C ₉ H ₁₀	9.4	34.8	47.6	61								

Compound		Pressure, mm. Hg											Normal boiling point, °C.
Name	Formula	1	5	10	20	40	60	100	200	400	760		
Temperature, °C.													
2-Fluorotoluene.....	C ₆ H ₅ F	-21.2	-2.2	+4.9	21.4	34.7	43.7	53.3	73.0	92.4	114.8	-80	
3-Fluorotoluene.....	C ₆ H ₅ F	-22.4	-0.3	+11.0	25.4	37.0	45.8	57.5	75.4	93.4	116.0	-110.8	
4-Fluorotoluene.....	C ₆ H ₅ F	-21.8	+0.3	11.0	24.0	37.0	46.3	58.1	76.0	94.1	117.0	-92	
Formaldehyde.....	CH ₂ O	70.5	96.3	109.5	122.5	137.5	147.0	157.5	173.0	193.5	210.5	8.2	
Formic acid.....	CH ₂ NO	-20.0	-5.0	+2.1	10.3	21.0	30.4	40.8	61.4	80.3	100.6	8.2	
trans-Formyl chloride.....	C ₆ H ₅ ClO	+15.0	38.5	51.6	65.0	79.5	92.4	105.9	120.0	140.0	160.0	8.2	
Furfural (2-furaldehyde).....	C ₅ H ₄ O	18.5	42.4	54.0	67.8	82.1	91.5	103.4	121.8	141.8	161.0	8.2	
Furfuryl alcohol.....	C ₅ H ₆ O	31.0	56.0	64.0	81.0	95.7	104.0	115.9	133.7	151.8	170.0	8.2	
Geraniol.....	C ₁₅ H ₂₆ O	69.2	90.8	110.0	125.4	141.4	151.5	165.3	183.6	207.6	230.0	8.2	
Geranyl acetate.....	C ₁₇ H ₃₂ O	75.5	102.7	117.9	133.0	150.0	160.2	175.2	193.6	219.4	243.5	8.2	
Geranyl n-butyrate.....	C ₁₉ H ₃₆ O	96.8	125.2	139.0	153.0	170.1	180.2	195.8	214.2	235.0	257.4	8.2	
Geranyl isobutyrate.....	C ₁₉ H ₃₆ O	90.9	119.4	133.0	147.9	164.0	174.0	187.7	207.6	235.0	257.4	8.2	
Geranyl formate.....	C ₁₇ H ₃₂ O	90.9	119.4	133.0	147.9	164.0	174.0	187.7	207.6	235.0	257.4	8.2	
Glutaric acid.....	C ₅ H ₈ O	61.8	90.3	104.3	119.8	136.2	146.2	160.7	182.6	205.8	230.0	8.2	
Glutaric anhydride.....	C ₅ H ₈ O	155.5	183.8	196.0	210.4	228.3	238.5	257.0	285.0	305.0	330.0	8.2	
Glutaronitrile.....	C ₅ H ₆ N ₂	100.8	133.3	149.5	166.0	183.5	196.2	212.5	236.5	261.0	287.0	8.2	
Glutaryl chloride.....	C ₅ H ₇ ClO	91.3	125.7	140.0	156.5	176.4	189.5	205.5	230.0	257.4	286.2	8.2	
Glycerol.....	C ₃ H ₈ O	56.1	82.7	97.8	112.5	128.5	140.5	151.8	172.4	195.3	217.0	8.2	
Glycerol diethylacrylate (1,3-diaceto-2-propanol).....	C ₁₁ H ₁₈ O	125.5	133.8	147.2	162.2	178.0	189.1	199.1	215.8	237.3	261.0	8.2	
Glycidol.....	C ₃ H ₆ O	29.0	52.2	64.7	78.0	93.0	104.0	120.0	140.0	163.0	188.0	8.2	
Glycolide (1,4-dioxane-2,6-dione).....	C ₄ H ₆ O	34.3	64.1	77.1	90.8	106.1	115.8	128.0	147.8	168.0	188.0	8.2	
Guanidol (2-methoxyphenol).....	C ₇ H ₈ O	103.0	114.6	132.0	146.4	164.0	173.2	184.0	194.0	205.0	216.0	8.2	
Hexamethylenes.....	C ₆ H ₁₂	32.4	79.1	92.0	106.0	121.4	131.0	144.0	162.7	184.1	205.0	8.2	
Hexadecane.....	C ₁₆ H ₃₄	152.6	188.0	205.4	223.2	243.4	258.3	277.0	296.5	318.0	340.0	8.2	
Heptadecane.....	C ₁₇ H ₃₆	211.7	248.6	266.8	284.6	303.7	318.3	335.0	359.4	385.0	410.4	8.2	
Heptadecyl alcohol.....	C ₁₇ H ₃₆ O	115.0	145.2	160.0	177.7	195.8	207.3	223.0	247.4	274.5	303.0	8.2	
n-Heptane.....	C ₇ H ₁₆	12.0	32.7	43.0	54.0	66.3	74.0	84.0	102.6	125.5	155.0	8.2	
Heptanoic acid (caproic acid).....	C ₇ H ₁₄ O	-34.0	-12.7	-2.1	+9.5	22.3	36.4	41.8	54.7	70.0	84.4	8.2	
1-Heptanol.....	C ₇ H ₁₆ O	78.0	101.3	113.2	123.6	139.5	148.5	160.0	179.5	199.4	221.3	8.2	
Heptanoyl chloride (caproyl chloride).....	C ₇ H ₁₃ ClO	42.4	64.3	74.7	83.8	99.8	108.0	119.5	134.6	153.6	174.0	8.2	
2-Heptene.....	C ₇ H ₁₄	34.2	54.6	64.3	75.0	86.4	95.5	102.7	116.3	130.7	145.0	8.2	
Heptylbenzene.....	C ₁₄ H ₂₀	-35.8	-14.1	-3.5	+4.3	16.4	29.5	36.0	41.3	54.4	78.1	8.2	
Heptyl cyanide (capronitrile).....	C ₇ H ₁₃ N	64.0	94.6	110.0	126.0	144.0	154.0	170.2	195.3	217.8	244.0	8.2	
Hexachlorobenzene.....	C ₆ Cl ₆	21.0	47.6	61.6	76.3	92.4	103.0	116.8	137.7	160.0	184.0	8.2	
Hexamethylenes.....	C ₆ H ₁₂	114.4	149.3	166.4	183.7	202.6	219.0	235.5	258.5	283.5	309.4	8.2	
Hexadecane.....	C ₁₆ H ₃₄	32.7	49.8	73.5	87.4	102.5	112.0	124.2	143.1	163.0	183.6	8.2	
1-Hexadecanol.....	C ₁₆ H ₃₄ O	204.0	240.0	257.4	275.8	295.3	307.8	323.2	348.4	374.0	399.0	8.2	
n-Hexamethyl alcohol (cetyl alcohol).....	C ₁₆ H ₃₄ O	105.3	135.2	149.8	164.7	181.3	192.2	208.5	231.7	258.3	287.5	8.2	
n-Hexamethylenes (cetylamine).....	C ₁₆ H ₃₃ N	101.6	131.7	146.2	162.0	178.0	190.0	203.5	228.0	250.0	274.0	8.2	
Hexamethylbenzene.....	C ₆ H ₁₂	122.7	158.3	176.0	197.8	219.8	234.3	251.7	280.2	312.7	349.0	8.2	
n-Hexane.....	C ₆ H ₁₄	125.6	157.6	177.0	195.7	215.7	228.8	245.8	272.2	300.4	330.0	8.2	
1-Hexanol.....	C ₆ H ₁₄ O	-53.9	-34.5	-25.0	-14.1	-2.3	+5.4	15.0	31.6	49.6	68.7	8.2	
2-Hexanol.....	C ₆ H ₁₄ O	24.4	47.2	58.2	70.3	83.7	92.0	102.8	119.6	138.0	157.0	8.2	
3-Hexanol.....	C ₆ H ₁₄ O	14.6	34.8	45.0	55.9	67.9	76.0	87.3	103.7	121.0	139.0	8.2	
1-Hexene.....	C ₆ H ₁₂	-12.5	25.7	36.7	49.0	62.2	70.7	81.8	98.3	117.0	135.5	8.2	
n-Hexyl levulinate.....	C ₁₈ H ₃₄ O	-57.5	-36.0	-28.1	-17.2	-5.0	+2.8	13.0	29.0	46.0	66.0	8.2	
n-Hexyl phenyl ketone (phenylhexanone).....	C ₁₂ H ₂₀ O	90.0	120.0	134.7	150.2	167.8	179.0	193.6	215.7	241.0	266.3	8.2	
Hydroxyacetic acid.....	CH ₂ NO	100.0	130.3	145.5	161.0	178.9	189.8	204.2	225.0	248.3	271.3	8.2	
Hydroxyacetic acid.....	CH ₂ NO	102.2	133.5	148.7	165.0	183.3	194.0	209.0	230.0	255.0	279.0	8.2	
Hydroxyacetic acid.....	CH ₂ NO	-71.0	-55.3	-47.7	-39.7	-30.9	-25.1	-17.6	-5.3	+10.2	25.9	8.2	
4-Hydroxybutyric acid.....	C ₄ H ₈ O	132.4	153.3	163.5	174.6	192.0	203.0	216.5	238.0	262.5	286.2	8.2	
n-Hydroxybutyric acid.....	C ₄ H ₈ O	121.2	153.2	169.7	186.8	206.0	217.5	233.5	256.4	282.6	310.0	8.2	
n-Hydroxybutyrolactone.....	C ₄ H ₆ O	73.5	98.5	110.5	123.8	138.0	146.4	157.0	175.2	193.8	212.0	8.2	
4-Hydroxy-3-methyl-2-pentanone.....	C ₅ H ₁₀ O	41.0	65.6	77.8	90.7	104.8	113.9	125.0	142.0	159.8	178.0	8.2	
4-Hydroxy-4-methyl-2-pentanone.....	C ₅ H ₁₀ O	44.6	69.3	81.0	94.0	108.2	117.4	129.0	146.5	165.5	185.0	8.2	
3-Hydroxypropionitrile.....	C ₃ H ₅ NO	22.0	46.7	58.8	72.0	86.7	96.0	108.2	125.0	145.5	167.9	8.2	
Iodene.....	C ₂ H ₄ I	58.7	87.6	102.0	117.9	134.1	144.7	157.7	173.0	190.0	211.0	8.2	
Iodobenzene.....	C ₆ H ₅ I	16.4	44.3	58.5	73.9	90.7	100.8	114.7	135.4	157.6	181.4	8.2	
Iodoacetone.....	C ₃ H ₅ I	24.1	50.6	64.0	79.3	94.4	105.0	118.3	139.9	163.9	188.6	8.2	
2-Iodobenzene.....	C ₆ H ₄ I	70.0	96.2	109.0	123.0	138.1	147.7	159.8	179.0	199.3	219.5	8.2	
n-Iodotoluene.....	C ₇ H ₇ I	79.5	104.8	123.0	139.0	155.6	166.3	181.2	202.5	225.2	250.0	8.2	
Isoprene.....	C ₅ H ₈	-79.8	-62.3	-53.3	-41.5	-32.6	-25.4	-16.0	-1.2	+15.4	32.4	8.2	
Isopropyl alcohol.....	C ₃ H ₈ O	77.7	108.4	123.7	140.2	157.8	168.7	184.5	207.8	231.8	257.0	8.2	
Leucic acid.....	C ₆ H ₁₂ O	121.0	150.6	166.0	183.6	201.4	212.7	227.5	249.8	273.0	299.2	8.2	
Levulinic acid.....	C ₅ H ₈ O	28.1	54.9	68.0	82.7	98.3	108.4	121.8	142.0	164.0	187.0	8.2	
Levulinic acid.....	C ₅ H ₈ O	102.0	128.1	141.8	154.1	169.5	178.0	190.2	208.5	227.4	245.8	8.2	
d-Limonene.....	C ₁₀ H ₁₆	14.0	40.4	53.8	68.2	84.3	94.6	108.3	125.3	151.4	175.0	8.2	
Linyl acetate.....	C ₁₀ H ₁₈ O	55.4	82.5	96.0	111.4	127.7	138.1	151.8	173.3	195.2	220.0	8.2	
Maleic anhydride.....	C ₄ H ₂ O	44.0	67.3	78.7	95.0	111.8	122.0	135.8	155.9	179.5	202.0	8.2	
Methane.....	CH ₄	-9.7	35.7	48.3	62.7	78.3	88.6	102.1	122.7	146.0	169.5	8.2	
1-Menthol.....	C ₁₀ H ₁₈ O	56.0	83.2	96.0	110.3	126.1	136.1	149.4	168.3	190.2	212.0	8.2	
Menthyl acetate.....	C ₁₂ H ₂₂ O	57.4	83.8	100.0	115.4	132.1	142.5	156.7	178.8	202.8	227.0	8.2	
benzoic acid.....	C ₇ H ₆ O	123.2	154.2	170.0	186.3	204.3	215.8	230.4	253.2	277.1	301.0	8.2	
Mentyl oxide.....	C ₁₀ H ₁₈ O	47.3	75.8	90.0	105.8	123.0	134.0	148.0	169.8	194.2	219.0	8.2	
Mesityl oxide.....	C ₈ H ₈ O	-8.7	+14.1	26.0	37.9	51.7	60.4	72.1	90.0	109.8	130.0	8.2	
Methacrylic acid.....	C ₄ H ₆ O	25.5	43.5	60.0	72.7	86.4	95.3	106.6	122.9	142.5	161.0	8.2	
Methacrylonitrile.....	C ₄ H ₅ N	-44.5	-23.3	-12.5	-0.6	+12.5	21.5	32.8	50.0	70.3	90.3	8.2	
Methanethiol.....	CH ₃ S	-205.9	-199.0	-193.5	-187.7	-183.1	-178.4	-173.4	-168.0	-161.5	-152.5	8.2	
Acetylenecarboxylic acid.....	C ₂ H ₂ O	-90.7	-75.3	-67.5	-58.8	-49.3	-38.1	-24.8	-10.1	+4.0	+12.1	8.2	
N-Methylacetamide.....	C ₃ H ₇ NO	32.3	79.3	92.0	106.5	122.0	131.8	144.3	163.5	184.2	204.0	8.2	
Methyl acetate.....	C ₃ H ₆ O	-37.2	-38.6	-29.3	-19.1	-7.9	-0.5	+9.4	24.0	40.0	57.8	8.2	
acetylene (propyne).....	C ₂ H ₂	-111.0	-97.9	-80.5	-62.9	-44.3	-24.8	-4.3	+9.4	24.0	40.0	8.2	
ac													

Compound	Name	Formula	Pressure, mm. Hg											M.B. log mm. °C.
			Temperature, °C.											
			1	5	10	20	40	60	100	200	400	760		
N-Methylamine		C ₂ H ₇ N	36.0	62.8	76.2	90.3	106.0	115.8	129.8	149.5	172.8	193.5	-57	
Methyl anthracene		C ₁₄ H ₁₀	77.4	109.0	124.2	141.5	159.7	172.0	187.8	212.4	238.5	265.3	-34	
Isocaproic acid		C ₆ H ₁₂ O ₂	39.0	64.4	77.3	91.8	107.8	117.4	130.8	151.4	174.7	199.3	-12.5	
2-Methylpentan-3-one		C ₆ H ₁₂ O	70.0	97.5	111.2	125.5	141.2	153.9	163.9	183.2	204.5	225.3	-15.4	
α-Methylthiobenzyl alcohol		C ₈ H ₁₀ S	49.0	75.2	88.0	102.1	117.8	127.4	140.3	159.0	180.7	204.0	-45	
Methyl bromide		CH ₃ Br	-96.3	-80.6	-72.8	-64.0	-54.2	-46.0	-39.4	-26.5	-11.9	+3.4	-135	
2-Methyl-1-butene		C ₅ H ₁₀	-89.1	-72.8	-64.3	-54.8	-44.1	-37.3	-28.0	-13.8	+2.3	20.2	-135	
2-Methyl-2-butene		C ₅ H ₁₀	-75.4	-57.0	-47.9	-37.9	-26.7	-19.4	-9.9	+4.9	21.6	34.9	-130	
Methyl isobutyl carbamate (2-methyl-4-pentanone)		C ₇ H ₁₄ O ₂	-0.3	+22.1	33.3	45.4	58.2	67.0	78.0	94.9	113.3	131.7	-36.9	
n-Butyl ketone (2-hexanone)		C ₆ H ₁₂ O	+7.7	28.8	38.8	50.0	62.0	69.0	79.8	94.3	111.0	127.5	-84.7	
Isobutyl ketone (4-methyl-2-pentanone)		C ₆ H ₁₂ O	-1.4	+19.7	30.0	40.8	52.0	60.4	70.4	85.6	102.0	119.0	-84.7	
n-Butyrate		C ₄ H ₈ O ₂	-26.8	-5.5	+5.0	16.7	29.4	37.4	48.0	64.3	83.1	102.3	-48	
Isobutyrate		C ₄ H ₈ O ₂	-34.1	-13.0	-2.9	+8.4	21.0	28.9	39.6	55.7	73.6	92.6	-48.7	
Caproic acid		C ₆ H ₁₂ O ₂	63.7	93.5	108.0	123.0	139.0	148.6	161.5	181.6	202.9	224.0	-14	
Caproic acid		C ₆ H ₁₂ O ₂	+3.0	30.0	42.0	55.4	70.0	79.7	91.4	109.8	129.8	150	-80	
Caprylate		C ₈ H ₁₆ O ₂	34.2	61.7	74.9	89.0	103.3	115.3	128.0	148.1	170.0	193.0	-97.7	
Chloride		CH ₃ Cl	-79.5	-59.5	-48.4	-38.0	-26.0	-16.0	-6.0	+4.0	24.0	44.0	-135	
Chloroacetic acid		CH ₂ ClCO ₂ H	-2.9	19.0	30.0	41.5	54.5	63.0	73.5	90.5	109.5	130.3	-31.9	
Cinnamic acid		C ₉ H ₈ O ₂	77.4	108.1	123.0	140.0	157.9	170.0	185.8	209.4	235.0	263.0	-33.4	
α-Methylcinnamic acid		C ₉ H ₈ O ₂	125.7	155.0	169.8	185.2	201.8	212.0	224.0	245.0	266.6	288.0	-126.4	
Methylcyclohexane		C ₇ H ₁₄	-35.9	-14.0	-3.2	+8.7	22.0	30.5	42.1	59.4	79.6	100.9	-142.4	
Methylcyclopentane		C ₆ H ₁₂	-53.7	-33.8	-23.7	-12.8	-0.4	+7.2	17.9	34.0	52.3	71.8	-11.3	
Methylcyclopentane		C ₆ H ₁₂	-96.0	-80.6	-72.8	-64.0	-54.2	-46.0	-39.4	-26.5	-11.9	+3.4	-135	
Methyl n-decyl ketone (n-decane-2-one)		C ₁₂ H ₂₄ O	77.1	106.0	120.4	136.0	152.4	163.8	177.5	199.0	222.5	246.5	-7.6	
dichloroacetic acid		CH ₂ ClCO ₂ H	3.2	26.7	38.1	50.7	64.7	73.6	85.4	103.2	122.6	143.0	-32.8	
N-Methylphenylamine		C ₈ H ₉ N	103.5	134.0	149.7	165.8	184.0	195.4	210.1	232.8	257.0	282.0	-96.7	
Methyl n-dodecyl ketone (2-tetradecanone)		C ₁₄ H ₂₈ O	99.3	130.0	145.7	161.5	179.8	191.4	206.0	228.2	253.3	278.0	-52.8	
Methyl n-tridecyl ketone (2-pentadecanone)		C ₁₅ H ₃₀ O	-35.1	-13.2	-2.4	+9.7	25.3	31.6	42.3	58.5	79.0	96.6	-36.7	
Chloride (dichloromethane)		CH ₂ Cl ₂	-70.0	-52.1	-43.3	-33.4	-22.3	-15.7	-6.3	+8.0	24.1	40.7	-85.9	
Methyl ethyl ketone (2-butanone)		C ₅ H ₁₀ O	-48.3	-28.0	-17.7	-6.5	+4.0	14.0	25.0	41.6	60.0	79.4	-114.5	
2-Methyl-3-pyridine		C ₇ H ₇ N	-24.0	-1.4	+9.5	21.7	35.2	43.9	55.7	73.6	94.0	115.6	-90	
3-Methyl-3-pyridine		C ₇ H ₇ N	-25.9	-1.4	+9.5	22.3	36.2	45.0	57.1	75.3	96.2	118.3	-90	
Methyl fluoride		CH ₃ F	-147.3	-137.0	-131.6	-125.9	-119.1	-115.0	-109.0	-99.9	-89.5	-76.2	-59.8	
formic acid		C ₁ H ₂ O ₂	-74.2	-57.0	-48.6	-39.2	-28.7	-21.9	-12.9	+4.8	16.0	32.0	-118.2	
Methylthiobenzyl alcohol		C ₈ H ₁₀ S	93.8	125.4	141.8	157.7	177.5	189.9	205.0	229.1	253.5	282.5	-64.4	
Methyl glycolate		C ₃ H ₆ O ₃	+9.6	33.7	45.3	58.1	72.3	81.8	93.7	111.8	131.7	151.5	-109.5	
2-Methylheptadecane		C ₁₈ H ₃₈	119.8	152.0	168.7	186.0	204.8	216.3	231.5	254.5	279.8	306.5	-120.6	
2-Methylheptadecane		C ₁₈ H ₃₈	-21.0	+1.3	12.3	24.4	37.9	46.6	58.3	76.0	96.2	117.6	-121.1	
3-Methylheptadecane		C ₁₈ H ₃₈	-19.8	+2.6	13.3	25.4	38.9	47.6	59.4	77.1	97.4	118.9	-120.6	
4-Methylheptadecane		C ₁₈ H ₃₈	-20.4	+1.5	12.4	24.5	38.0	46.6	58.3	76.1	96.3	117.7	-121.1	
2-Methyl-2-octene		C ₈ H ₁₆	-16.1	+6.7	17.8	30.4	44.0	52.8	64.6	82.3	102.2	122.5	-140.3	
6-Methyl-2-octene-3-ol		C ₈ H ₁₆ O	41.6	65.0	76.7	89.3	102.7	111.5	122.6	139.5	156.6	174.3	-118.2	
6-Methyl-2-octene-3-ol		C ₈ H ₁₆ O	41.9	66.0	77.8	90.4	104.0	112.8	123.8	140.0	156.6	174.3	-118.2	
2-Methylheptane		C ₈ H ₁₈	-40.4	-19.5	-9.1	+2.3	14.9	23.5	34.1	50.8	69.8	90.0	-64.4	
3-Methylheptane		C ₈ H ₁₈	-39.0	-18.1	-7.8	+3.6	16.4	24.3	35.6	52.4	71.6	91.9	-64.4	
Methyl iodide		CH ₃ I	-87.8	-55.0	-45.8	-35.6	-24.2	-16.9	-8.0	+4.0	25.3	42.4	-135	
laurel		C ₁₂ H ₂₄ O	87.8	117.9	133.2	149.0	166.0	176.8	190.8	213.4	238.5	265.3	-34	
levulinic acid		C ₅ H ₈ O ₃	39.8	66.4	79.7	93.7	109.5	119.3	133.0	153.4	175.8	197.7	-18.5	
methacrylate		C ₅ H ₈ O ₂	-30.5	-10.0	+1.0	11.0	25.5	34.5	47.0	63.0	82.0	101.0	-100	
myristic acid		C ₁₄ H ₂₈ O ₂	115.0	145.7	160.8	177.8	195.8	207.5	222.6	245.3	269.8	295.5	-33.5	
α-naphthyl ketone (1-naphthyl ketone)		C ₁₅ H ₁₂ O	115.6	146.3	161.5	178.4	196.8	208.6	223.8	246.7	270.5	295.5	-33.5	
β-naphthyl ketone (2-naphthyl ketone)		C ₁₅ H ₁₂ O	120.2	152.3	168.5	185.7	203.8	214.7	229.8	251.6	275.8	301.0	-30	
n-octyl ketone (undecane-2-one)		C ₁₁ H ₂₂ O	68.2	95.5	108.9	123.1	139.0	148.6	161.0	181.2	202.3	224.0	-100	
palmitic acid		C ₁₆ H ₃₂ O ₂	134.3	166.8	184.3	202.0	214.3	226.7	242.0	263.8	291.7	319.5	-134	
n-pentadecyl ketone (2-heptadecanone)		C ₁₇ H ₃₄ O	129.6	161.6	178.0	196.4	214.3	226.7	242.0	263.8	291.7	319.5	-118	
2-Methylpentane		C ₆ H ₁₄	-60.9	-41.7	-32.1	-21.4	-9.7	-1.9	+8.1	24.1	41.6	60.3	-100	
3-Methylpentane		C ₆ H ₁₄	-59.0	-39.8	-30.1	-19.4	-7.3	+0.1	10.5	26.5	44.2	63.3	-37.3	
2-Methyl-1-pentanol		C ₆ H ₁₄ O	13.4	38.0	49.6	61.6	74.7	83.4	94.2	111.3	129.8	147.9	-140.3	
2-Methyl-2-pentanol		C ₆ H ₁₄ O	-4.3	+16.8	27.6	38.8	51.3	58.8	69.2	85.0	102.6	121.2	-100	
Methyl n-pentyl ketone (2-heptanone)		C ₇ H ₁₄ O	19.3	43.5	55.3	67.7	81.2	89.8	100.0	116.1	133.2	150.2	-37.3	
phenyl ether (anisole)		C ₆ H ₅ O	+5.4	30.0	42.2	55.8	70.7	80.1	93.0	112.3	133.8	155.3	-87.5	
2-Methylpropane		C ₄ H ₁₀	-103.1	-86.5	-73.4	-61.9	-43.8	-37.7	-29.3	-16.7	-2.2	+9.9	-135	
Methyl propionate		C ₅ H ₁₀ O ₂	-42.0	-21.5	-11.8	-1.0	+11.0	18.7	29.0	44.2	61.8	79.8	-100	
4-Methylpropionamide		C ₅ H ₁₁ NO	59.6	89.3	103.8	120.2	138.0	149.3	164.2	187.4	212.7	238.5	-77.8	
2-Methylpropionyl bromide		C ₄ H ₇ BrO	13.5	38.4	50.6	64.1	79.4	88.8	101.6	120.5	141.7	163.0	-92	
Methyl propyl ether		C ₅ H ₁₂ O	-72.2	-54.3	-45.4	-35.4	-24.3	-17.4	-8.1	+6.0	22.5	39.1	-135	
n-propyl ketone (2-pentanone)		C ₅ H ₁₀ O	-12.0	+8.0	17.9	28.5	39.8	47.3	56.8	71.0	86.8	103.3	-100	
isopropyl ketone (3-methyl-2-butanone)		C ₅ H ₁₀ O	-19.9	-1.0	+8.3	18.3	29.6	36.2	45.5	59.0	73.8	88.9	-100	
2-Methylquinoline		C ₉ H ₇ N	75.3	104.0	119.0	134.0	150.8	161.7	176.2	197.8	217.7	246.5	-33.5	
Methyl salicylate		C ₉ H ₁₀ O ₃	54.0	81.6	95.3	110.0	126.2	136.7	150.0	172.6	197.5	223.2	-23.2	
4-Methyl styrene		C ₉ H ₈	7.4	34.0	47.1	61.8	77.8	83.3	102.2	121.8	143.0	165.4	-100	
Methyl n-tetradecyl ketone (2-hexadecanone)		C ₁₆ H ₃₂ O	109.8	151.5	167.3	184.6	203.7	215.0	230.5	254.4	279.8	307.0	-31	
thioacetate		C ₂ H ₂ S	-14.0	+9.8	21.6	34.5	49.0	58.1	70.4	89.8	110.4	132.9	-51	
isothioacetate		C ₂ H ₂ NS	-34.7	-8.3	+5.4	20.4	38.2							

Compound		Pressure, mm. Hg										Mol. wt.
Name	Formula	1	5	10	20	40	60	100	200	400	760	
Temperature, °C.												
2-Naphthylamine	C ₁₀ H ₉ N	108.0	141.6	157.6	175.8	195.7	208.1	221.3	249.7	277.4	306.1	111.5
Nicotin	C ₆ H ₅ N ₂	61.6	91.8	107.2	123.7	142.1	154.7	169.5	193.6	219.8	247.3	71.5
2-Nitroaniline	C ₆ H ₅ NO ₂	104.0	135.7	150.4	167.7	186.0	197.6	213.0	236.3	260.0	284.5	114
3-Nitroaniline	C ₆ H ₅ NO ₂	119.3	151.9	167.8	185.5	204.2	216.5	232.1	255.3	280.2	305.7	114.5
4-Nitroaniline	C ₆ H ₅ NO ₂	142.4	177.6	194.4	213.2	234.2	245.9	261.8	284.5	310.2	336.0	114.5
2-Nitrobenzaldehyde	C ₇ H ₅ NO ₂	83.0	117.7	133.4	150.0	168.8	180.7	196.2	220.0	246.8	273.5	115.5
3-Nitrobenzaldehyde	C ₇ H ₅ NO ₂	96.2	127.4	142.8	159.0	177.7	189.5	204.3	227.4	252.1	278.3	115.5
Nitrobenzene	C ₆ H ₅ NO ₂	44.4	71.6	84.9	99.3	115.4	125.8	139.9	161.2	185.8	210.6	115.5
Nitroethane	C ₂ H ₅ NO ₂	-21.0	+1.5	12.5	24.8	38.0	46.5	57.8	74.8	94.0	114.0	75
Nitropropane	C ₃ H ₇ NO ₂	127	167	183	210	235	251	268	298	328	358	75
Nitromethane	CH ₃ NO ₂	-29.0	-7.9	+2.8	14.1	27.5	35.5	46.6	63.5	82.0	101.2	45
2-Nitrophenol	C ₆ H ₄ NO ₂	49.3	76.8	90.4	105.0	122.1	132.6	146.4	167.6	191.0	214.5	110
2-Nitrophenyl acetate	C ₈ H ₇ NO ₂	100.0	128.0	142.0	155.0	172.0	181.7	194.1	213.0	233.5	253.0	110
1-Nitropropane	C ₃ H ₇ NO ₂	-9.6	+13.5	25.3	37.9	51.8	60.5	72.3	90.2	110.6	131.4	75
2-Nitropropane	C ₃ H ₇ NO ₂	-18.8	+4.1	15.8	28.2	41.8	50.5	62.0	80.0	99.8	120.3	75
2-Nitrotoluene	C ₇ H ₇ NO ₂	50.0	79.1	93.8	109.6	128.3	137.4	151.5	173.7	197.7	222.3	110
3-Nitrotoluene	C ₇ H ₇ NO ₂	50.2	81.0	96.0	112.8	130.7	142.5	156.9	180.5	204.8	229.5	110
4-Nitrotoluene	C ₇ H ₇ NO ₂	53.7	85.0	100.0	117.7	136.0	147.9	163.0	186.7	211.2	235.3	110
4-Nitro-1,3-xylene (4-nitro-m-xylene)	C ₈ H ₇ NO ₂	65.4	95.0	109.6	125.8	143.3	153.8	168.5	191.7	217.5	244.0	110
Nonane	C ₉ H ₂₀	254.2	289.8	326.4	363.2	400.0	436.8	473.6	510.4	547.2	584.0	114
Nonadecane	C ₁₉ H ₄₀	133.2	166.3	193.5	220.0	246.8	273.6	300.4	327.2	354.0	380.8	114
Nonadecane	C ₁₉ H ₄₀	+1.4	23.8	38.0	51.2	66.0	75.5	88.1	107.5	128.2	150.8	114
1-Nonanol	C ₉ H ₁₉ O	59.5	86.1	99.7	113.8	129.0	139.0	151.3	170.5	192.1	213.5	114
2-Nonanol	C ₉ H ₁₉ O	32.1	59.0	72.3	87.2	103.4	113.8	127.4	148.2	171.2	195.0	114
Octadecane	C ₁₈ H ₃₈	226.5	260.3	297.4	334.2	370.0	405.8	441.6	477.4	513.2	549.0	114
Octadecane	C ₁₈ H ₃₈	119.6	152.1	189.6	227.1	264.6	297.1	334.6	372.1	409.6	447.1	114
Octadecane	C ₁₈ H ₃₈	-14.0	+8.3	19.2	31.5	45.1	53.8	65.7	83.6	104.6	128.4	114
Octadecane (1-octadecane)	C ₁₈ H ₃₈	54.0	76.5	88.3	101.0	115.2	123.5	135.2	152.0	173.8	195.2	114
2-Octadecane	C ₁₈ H ₃₈	23.6	48.4	60.9	74.3	89.8	99.0	111.7	130.4	151.0	172.9	114
Octyl acetate	C ₁₀ H ₁₉ O ₂	58.5	87.7	102.0	117.8	135.6	145.4	159.1	180.2	204.0	227.8	114
Octyl iodide (1-octadecane)	C ₁₈ H ₃₇ I	45.8	74.8	90.0	105.0	122.8	132.6	146.4	167.6	191.0	214.5	114
Octyl iodide	C ₁₈ H ₃₇ I	176.5	208.5	235.0	262.0	289.0	316.0	343.0	370.0	397.0	424.0	114
Octyl iodide	C ₁₈ H ₃₇ I	121.6	154.6	171.8	190.0	210.0	222.6	239.5	264.1	292.3	321.0	114
Octyl iodide	C ₁₈ H ₃₇ I	153.6	188.1	205.8	223.8	244.4	256.0	271.5	293.7	316.0	338.8	114
Octyl iodide	C ₁₈ H ₃₇ I	134.3	168.3	185.8	204.2	223.8	236.6	251.5	277.1	304.5	332.0	114
Octyl iodide	C ₁₈ H ₃₇ I	108.2	125.0	137.4	149.8	163.7	172.3	184.4	203.1	227.5	253.5	114
Octyl iodide	C ₁₈ H ₃₇ I	98.6	129.7	144.3	160.0	178.5	190.1	205.5	227.0	251.6	278.0	114
Octyl iodide	C ₁₈ H ₃₇ I	+1.0	27.2	39.8	53.9	69.9	80.0	93.5	114.0	137.2	160.5	114
Octyl iodide	C ₁₈ H ₃₇ I	96.2	130.0	148.0	166.0	186.2	199.0	216.0	241.8	269.3	299.0	114
Octyl iodide	C ₁₈ H ₃₇ I	194.2	230.0	248.2	266.1	285.6	298.4	314.0	339.0	365.4	390.5	114
Octyl iodide	C ₁₈ H ₃₇ I	91.6	121.0	135.4	150.2	167.7	178.4	194.0	216.1	242.8	270.5	114
1,3-Pentadiene	C ₅ H ₈	-71.8	-53.6	-45.0	-34.8	-23.4	-16.3	-6.7	+8.0	24.7	42.1	114
1,4-Pentadiene	C ₅ H ₈	-83.5	-66.2	-57.1	-47.7	-37.0	-26.0	-14.7	+8.3	26.1	42.1	114
Pentachlorobenzene	C ₅ Cl ₅	86.0	120.0	135.8	152.4	171.9	184.2	200.0	224.1	250.2	277.0	114
Pentachlorobenzene	C ₅ Cl ₅	90.0	123.8	140.7	158.1	178.2	191.0	208.0	230.3	257.2	285.0	114
Pentachlorobenzene	C ₅ Cl ₅	-76.6	-62.5	-50.1	-40.2	-29.2	-22.2	-12.6	+1.9	18.5	36.1	114
Pentachlorobenzene	C ₅ Cl ₅	-82.9	-65.8	-57.0	-47.3	-36.5	-26.6	-16.7	-3.9	+10.5	27.8	114
Pentachlorobenzene	C ₅ Cl ₅	-102.0	-85.4	-76.7	-67.2	-56.1	-45.0	-33.1	-21.7	-10.1	+9.5	114
2,3,4-Pentachlorobenzene	C ₅ Cl ₅	155.0	189.3	204.5	220.5	239.6	259.8	283.5	304.5	327.2	350.5	114
1-Pentene	C ₅ H ₁₀	-80.4	-63.3	-54.5	-46.0	-34.1	-27.1	-17.7	-3.4	+12.8	30.1	114
α-Phellandrene	C ₁₀ H ₁₆	20.0	45.7	58.0	72.1	87.8	97.6	110.6	130.6	152.0	175.0	114
Phenanthrene	C ₁₄ H ₁₀	118.2	154.3	173.0	193.7	215.8	229.9	249.0	277.1	308.0	340.2	114
Phenethyl alcohol (phenyl ethyl alcohol)	C ₈ H ₁₀ O	58.2	85.9	100.0	114.8	130.5	141.2	154.0	175.0	197.5	219.5	114
2-Phenethylamine	C ₈ H ₁₀ N	67.0	94.7	108.6	123.7	139.9	149.8	163.5	184.0	207.0	228.0	114
Phenol	C ₆ H ₆ O	40.1	62.4	73.8	86.0	100.1	108.4	121.4	139.0	160.0	181.9	114
2-Phenoxyethanol	C ₈ H ₁₀ O	78.0	105.6	121.2	136.0	152.2	163.2	175.5	197.6	221.0	245.3	114
2-Phenoxyethyl acetate	C ₁₀ H ₁₂ O ₂	82.6	113.5	128.0	144.5	162.3	174.0	189.2	211.5	235.0	259.7	114
Phenyl acetate	C ₈ H ₈ O ₂	35.2	64.0	78.0	92.3	108.1	118.1	131.0	151.2	173.5	195.9	114
Phenyl acetate	C ₈ H ₈ O ₂	97.0	127.0	141.3	156.0	173.6	184.5	198.2	219.5	243.0	265.5	114
Phenyl acetate	C ₈ H ₈ O ₂	60.0	89.0	103.5	119.4	136.3	147.7	161.8	184.2	208.5	233.5	114
Phenyl acetate	C ₈ H ₈ O ₂	48.0	75.3	89.0	103.6	119.8	129.8	143.5	163.8	186.0	210.0	114
Phenyl benzoate	C ₁₂ H ₁₀ O ₂	106.8	141.5	157.8	177.0	197.6	210.6	227.8	254.0	283.5	314.0	114
4-Phenyl-3-butan-2-one	C ₁₀ H ₁₂ O	81.7	112.2	127.4	143.8	161.3	172.6	187.8	211.0	235.4	261.0	114
Phenyl isocyanate	C ₇ H ₅ NO	10.6	36.0	48.5	62.5	77.7	87.7	100.6	120.8	142.7	165.6	114
Phenyl isocyanate	C ₇ H ₅ NO	12.0	37.0	49.7	63.4	78.9	88.0	101.0	120.8	142.3	165.0	114
Phenyl isocyanate	C ₇ H ₅ NO	67.5	96.5	111.3	126.4	144.0	154.2	169.3	191.3	214.6	240.0	114
Phenyl isocyanate	C ₇ H ₅ NO	66.7	95.9	110.0	125.9	143.4	153.6	168.0	189.8	213.0	239.5	114
m-Phenylenediamine (1,3-phenylenediamine)	C ₆ H ₈ N ₂	99.8	131.2	147.0	163.8	182.5	194.0	209.9	233.0	259.0	285.5	114
Phenylglyoxal	C ₈ H ₆ O ₂	71.8	101.6	115.8	131.5	148.2	158.7	173.5	195.4	218.2	243.5	114
Phenylglyoxal	C ₈ H ₆ O ₂	145.0	179.2	195.8	213.4	233.0	245.3	250.6	284.5	311.3	337.8	114
N-Phenylaminodithiophenol	C ₁₀ H ₁₀ N ₂ S ₂	98.0	128.5	144.0	159.9	178.0	189.8	204.5	225.7	251.2	276.5	114
1-Phenyl-1,3-pentadiene	C ₁₀ H ₁₄	100.0	131.6	146.2	163.3	180.3	192.2	205.9	227.9	251.8	275.0	114
2-Phenylphenol	C ₁₂ H ₁₀ O	74.7	102.4	116.0	131.2	147.4	156.8	170.3	191.2	212.8	235.0	114
3-Phenyl-1-propanol	C ₁₀ H ₁₂ O	47.2	75.6	89.8	105.5	122.5	133.3	147.7	169.6	194.0	218.5	114
Phenyl isothiocyanate	C ₇ H ₅ NS	42.0	68.3	81.5	95.6	111.3	121.4	134.0	153.5	173.3	197.2	114
Phorone	C ₈ H ₁₄ O	38.0	66.7	81.2	96.8	114.5	125.6	140.6	163.3	188.7	215.2	114
iso-Phorone	C ₈ H ₁₄ O	-92.9	-77.0	-69.3	-60.3	-50.3	-44.0	-35.6	-22.3	-7.6	+8.3	114
Phosgene (carbonyl chloride)	CCl ₂ O	96.5	121.5	134.0	151.7	172.0	185.3	202.3	224.0	250.8	280.0	114
Phthalic anhydride	C ₈ H ₄ O ₃	95.5	127.7	144.0	161.3	181.0	193.5	210.0	234.5	261.8	290.0	114
Phthalide	C ₈ H ₆ O	85.3	115.3	134.2	151.0	170.5	182.2	197.8	222.0	248.3	275.8	114
Phthaloyl chloride	C ₈ H ₄ Cl ₂ O	-11.1	+12.6	24.4	37.4	51.2	59.9	71.4	89.0	108.4	128.6	114
2-Picoline	C ₇ H ₇ N	163.4	196.2	212.0	229.3	247.0	258.2	272.0	294.5	318.5	342.1	114
Picoline	C ₇ H ₇ N	-1.0	+24.6	37.3	51.4	66.8	76.8	90.1	110.2	132.3	155.0	114
o-Picoline	C ₇ H ₇ N	+4.2	30.0	42.3</								

Compound	Name	Formula	Pressure, mm. Hg										Mol. wt.
			1	5	10	20	40	60	100	200	400	760	
Temperature, °C.													
Formaldehyde		CH_2O	87.0	117.4	132.0	146.0	165.7	177.6	191.7	214.3	238.5	263.0	30
Propane		C_3H_8	-129.9	-115.4	-108.5	-100.9	-92.4	-87.0	-79.6	-68.4	-55.6	-42.1	-107.1
Propylene		C_3H_6	17.5	43.8	57.0	71.5	87.7	97.8	111.7	132.0	154.7	179.0	-30.1
Propionitrile		$\text{C}_3\text{H}_5\text{NO}$	65.0	91.0	105.0	119.0	134.8	144.3	156.0	174.2	194.0	213.0	79
Propionic acid		$\text{C}_3\text{H}_7\text{O}_2$	4.4	28.0	39.7	52.0	65.8	74.1	85.8	102.5	122.0	141.1	-22
acetylene		C_2H_2	20.6	45.3	57.7	70.4	85.4	94.5	107.2	127.9	146.0	167.0	-45
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-35.0	-13.6	-3.0	+4.8	12.6	20.8	28.8	37.0	47.0	57.7	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	50.0	77.9	92.2	107.6	124.3	135.0	149.3	170.2	194.2	218.0	21
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-26.7	-5.4	+5.0	16.0	28.8	37.0	47.0	57.7	77.7	97.1	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-38.3	-17.4	-7.2	+4.2	17.0	25.1	35.7	47.0	60.8	77.7	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-15.0	+5.0	14.7	25.3	36.4	43.5	52.4	64.8	82.0	101.8	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-26.1	-7.0	+2.4	12.7	23.8	30.5	39.5	53.0	67.8	85.8	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-64.4	-46.3	-37.2	-27.1	-16.0	-8.0	+0.5	15.0	31.5	48.5	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	6.3	31.3	43.4	56.8	71.4	81.1	94.0	113.5	135.7	159.2	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	54.6	83.8	98.0	114.3	131.8	143.3	157.4	180.1	205.2	231.0	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-53.0	-33.4	-23.3	-12.4	-0.3	+7.5	18.0	34.0	52.0	71.0	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-61.8	-42.5	-32.6	-22.0	-10.1	-2.5	+4.0	23.0	41.5	60.0	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-1.6	+22.1	34.0	47.0	61.5	70.3	82.6	101.0	121.7	142.7	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-6.2	+16.8	28.3	40.6	54.3	63.0	73.9	91.8	112.0	133.9	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-16.3	+5.6	17.6	28.0	42.4	51.4	62.3	80.2	100.0	120.5	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	52.4	77.4	90.0	103.2	117.7	133.5	150.3	175.8	200.0	225.0	-91.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-69.3	-50.0	-41.0	-31.0	-19.5	-12.1	-2.5	+12.2	29.4	46.4	-122.8
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-78.8	-61.1	-52.0	-42.0	-31.0	-23.5	-13.7	+1.3	18.1	36.5	-117
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	+3.6	28.1	40.2	53.9	68.7	78.0	90.3	108.8	128.0	148.6	-117
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	9.7	32.3	43.5	55.6	68.8	77.2	88.0	104.7	123.0	150.0	-117
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-131.9	-120.7	-112.1	-104.7	-96.5	-91.3	-84.1	-73.3	-60.9	-47.7	-185
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	45.5	70.8	83.2	96.4	111.2	119.9	132.0	149.7	168.1	188.2	-185
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-75.0	-57.8	-49.0	-39.3	-28.4	-21.3	-12.0	+2.1	17.8	34.5	-112.1
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-43.0	-22.7	-12.6	-1.7	+10.8	15.8	29.5	45.3	62.6	81.3	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-52.0	-32.7	-22.7	-12.1	-0.2	+7.5	17.8	33.4	50.5	68.3	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	193.0	224.2	240.8	255.5	273.0	282.9	297.0	317.5	339.0	360.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-36.0	-13.5	-2.4	+10.0	23.6	32.1	43.8	61.6	81.8	102.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-43.3	-22.1	-11.7	0.0	+13.2	21.4	32.8	50.0	69.5	89.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	59.7	86.3	99.9	114.0	130.1	148.6	175.6	198.0	221.2	245.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	48.0	74.5	88.0	102.4	118.1	127.8	141.6	161.6	185.2	208.2	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-56.0	-36.3	-26.3	-15.4	-3.2	+4.6	15.3	31.5	47.4	64.4	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	76.0	107.9	123.4	140.3	159.0	171.4	187.6	211.8	238.5	266.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	133.2	165.4	181.0	197.7	215.4	227.0	242.3	264.0	288.2	313.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	56.6	83.8	97.0	111.7	127.5	137.7	150.3	170.1	192.6	214.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	62.0	90.3	104.1	119.8	136.2	146.6	160.2	182.0	205.0	228.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	67.0	94.7	108.0	123.4	139.8	149.7	163.3	184.0	206.1	228.2	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-14.2	+8.0	19.4	31.6	45.0	53.8	65.2	82.7	102.0	122.4	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-8.0	32.8	45.1	58.0	72.8	82.3	95.0	113.9	135.0	155.9	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	58.3	82.5	94.0	106.8	121.7	130.2	143.1	162.5	189.8	221.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-18.9	+2.5	13.2	24.8	38.0	46.8	57.8	75.0	95.6	115.4	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	104.0	138.3	154.0	170.6	187.7	197.7	206.5	228.7	253.3	278.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	98.0	129.8	145.7	161.8	179.8	191.6	206.5	228.7	253.3	278.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	151.7	167.7	183.3	204.2	216.3	232.0	253.3	281.5	309.0	333.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	69.7	97.7	114.2	130.0	147.8	158.6	173.8	196.1	221.0	247.4	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	21.4	45.8	57.9	70.8	85.3	94.1	106.5	124.7	144.7	165.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	59.7	89.6	103.8	119.8	136.7	148.1	163.2	186.2	212.3	237.7	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	63.5	92.7	107.8	123.7	141.6	152.0	167.6	190.0	214.5	240.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	108.4	138.0	152.1	168.0	185.3	195.8	209.8	230.8	253.4	276.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	63.8	93.0	107.6	123.0	140.1	150.3	165.1	186.2	210.0	233.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	113.7	136.0	146.2	156.8	172.2	182.0	193.4	210.0	230.5	256.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	183.0	215.7	232.0	250.0	268.2	279.8	294.5	312.2	332.8	353.3	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-39.0	-16.0	-4.0	+9.1	24.1	33.8	47.0	66.7	89.8	114.3	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	95.0	124.2	139.6	154.3	171.9	183.6	197.4	218.8	242.5	266.2	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	140.0	174.6	192.1	210.6	230.8	244.2	260.0	285.0	313.8	342.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	173.7	209.0	225.0	243.4	263.3	275.5	291.0	316.5	343.0	370.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	150.3	185.6	202.0	220.0	240.4	252.7	269.4	293.5	320.3	349.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-7.0	+18.0	30.8	44.6	59.8	69.5	82.0	101.3	122.5	145.2	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	86.0	115.6	129.8	145.2	161.8	172.2	186.3	207.8	230.0	254.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	172.8	205.5	219.5	238.2	254.6	265.4	279.8	300.5	322.8	345.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	92.0	115.0	128.2	145.3	163.0	174.0	189.0	212.0	237.0	261.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	115.0	143.2	157.0	174.0	192.0	203.0	217.4	240.0	265.5	287.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	52.8	80.4	94.3	109.8	126.0	136.3	150.1	171.2	194.3	217.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	32.3	58.0	70.6	84.8	100.0	109.8	122.7	142.0	163.3	185.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	58.0	83.3	95.7	108.5	123.2	132.6	144.0	161.5	181.0	200.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	65.0	95.5	110.0	126.0	144.0	155.1	170.0	192.5	217.5	243.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	63.8	93.7	108.5	124.5	142.2	152.6	167.5	190.0	214.0	240.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	183.8	219.6	237.6	255.3	276.3	288.4	305.2	330.5	358.0	386.4	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	68.5	99.6	114.7	131.2	149.2	160.0	175.7	198.0	225.5	254.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	58.2	89.0	104.1	121.6	140.0	152.0	168.0	193.7	220.0	246.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-37.5	-16.0	-5.0	+6.7	19.8	28.1	38.4	55.0	73.1	92.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-16.3	+7.4	19.3	32.1	46.7	56.0	68.0	87.2	108.2	130.3	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-3.8	+20.7	33.0	46.2	60.8	70.0	83.2	102.2	124.0	145.9	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	77.0	110.0	126.0	143.7	162.1	175.0	191.6	215.3	243.0	270.0	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	-20.6	+2.4	13.8	26.3	40.1	49.2	61.3	79.8	100.0	120.8	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	100.0	130.3	145.3	161.0	179.1	190.0	205.3	227.2	250.4	273.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	94.4	125.0	140.3	156.0	174.2	185.8	200.5	223.0	248.3	273.5	-92.9
Propionitrile		$\text{C}_3\text{H}_5\text{N}$	76.4	106.0	120.7	135.6	152.7						

Compound	Name	Formula	Pressure, mm. Hg											Boiling point, °C.
			1	5	10	20	40	60	100	200	400	760		
			Temperature, °C.											
Tetradecylamine	C ₁₄ H ₂₉ N	102.6	133.8	152.0	170.0	189.0	209.2	215.7	239.8	254.6	271.2			
Tetradecyltrimethylsilane	C ₁₇ H ₃₅ Si	120.0	150.7	166.2	183.5	201.5	218.5	227.8	250.0	275.0	290.0			
Tetradecylsilane	C ₁₄ H ₃₀ Si	16.0	40.3	52.4	65.4	81.1	98.7	103.4	120.0	146.2	168.5			
1,2,3,4-Tetramethylbenzene	C ₁₀ H ₁₄	63.7	96.2	111.6	127.4	145.8	156.7	172.4	196.0	221.4	248.0	11.6		
Tetramethylene glycol	C ₄ H ₁₀ O ₂	153.9	183.7	197.1	212.3	228.0	237.8	250.0	280.0	307.0	328.0			
Tetramethylene glycol chlorohydrin	C ₄ H ₈ ClO ₂	110.1	141.8	156.1	172.4	190.0	200.5	214.7	236.5	258.2	281.5			
Tetramethylsilane	C ₄ H ₁₀ Si	38.4	63.6	74.8	88.0	102.4	111.7	123.8	142.0	161.8	183.0	-136		
Tetralin	C ₁₀ H ₈	-1.0	+23.9	36.3	50.0	65.3	74.8	85.0	108.0	130.2	150.0			
1,2,3,4-Tetramethylbenzene	C ₁₀ H ₁₄	38.0	65.3	79.0	93.6	110.4	121.3	135.5	157.2	181.8	207.2	-31.0		
1,2,3,5-Tetramethylbenzene	C ₁₀ H ₁₄	42.6	68.7	81.8	95.6	111.3	121.8	135.7	155.7	180.0	204.4	-4.2		
1,2,4,5-Tetramethylbenzene	C ₁₀ H ₁₄	40.6	65.6	77.8	91.6	105.8	115.4	128.3	149.9	173.7	197.9	-24.0		
2,2,3,3-Tetramethylbutane	C ₈ H ₁₈	45.0	65.0	74.6	88.0	104.2	114.0	128.1	149.5	172.1	195.9	-79.5		
Tetramethylene dibromide (1,4-dibromobutane)	C ₄ H ₈ Br ₂	-17.4	+5.2	13.5	21.6	36.8	44.5	54.8	70.2	87.4	106.2	-102.2		
Tetramethyllead	C ₄ H ₁₀ Pb	32.0	58.8	72.4	87.4	104.0	115.1	128.7	149.8	173.8	197.5	-20		
Tetramethyltin	C ₄ H ₁₀ Sn	-29.0	-6.8	+1.4	16.4	30.3	39.2	50.8	68.8	89.0	110.0	-37.5		
Tetrapropylene glycol monomethyl ether	C ₈ H ₁₈ O ₂	-51.3	-31.0	-20.6	-9.3	+3.5	11.7	22.0	39.8	58.5	78.0			
Thiosacetic acid (mercaptosuccinic acid)	C ₂ H ₄ O ₂ S	116.6	147.8	163.0	179.8	197.7	209.0	223.5	245.0	268.3	292.7			
Thiodiglycol (2,2-thiodiglycol)	C ₂ H ₄ O ₂ S	60.0	87.7	101.5	115.8	131.8	142.0	154.0				-14.5		
Thiophene	C ₄ H ₄ S	42.0	96.0	125.0	165.0	210.0	240.5	285.0						
Thiophene (benzene ring)	C ₄ H ₄ S	-40.7	-20.8	-10.9	0.0	+12.5	20.1	30.5	46.5	64.7	84.4	-38.3		
o-Thiophene	C ₄ H ₄ S	18.4	43.7	56.0	69.7	84.2	93.9	106.4	125.8	146.7	168.0			
Thymol	C ₁₀ H ₁₄ O	38.3	65.7	79.3	93.7	110.0	120.2	134.0	154.2	177.8	201.0			
Thiobenzene	C ₆ H ₄ S	64.3	92.8	107.4	122.4	139.8	149.8	164.1	185.5	209.2	231.8	51.5		
Tiglic acid	C ₈ H ₁₆ O ₂	-25.0	-1.6	+10.0	23.2	37.0	45.0	57.7	75.4	95.5	116.4			
Tidionitrile	C ₆ H ₄ N ₂	32.0	58.8	72.4	87.4	104.0	115.1	128.7	149.8	173.8	197.5	64.5		
Toluene	C ₇ H ₈	-23.5	-2.4	+9.2	22.1	36.7	46.0	58.2	77.8	99.7	120.5			
Toluene-2,4-diamine	C ₇ H ₈ N ₂	-17.4	+5.2	13.5	21.6	36.8	44.5	54.8	70.2	87.4	106.2	-95.0		
2-Toluidine nitrate (2-toluidine)	C ₇ H ₉ N	106.5	137.2	151.7	167.9	185.7	196.5	211.5	232.0	256.0	280.0			
4-Toluidine nitrate (4-toluidine)	C ₇ H ₉ N	36.7	64.0	77.9	93.0	110.0	120.2	134.0	154.2	177.8	201.0	-15		
2-Toluidine	C ₇ H ₉ N	42.5	71.3	85.8	101.7	110.0	119.8	133.0	153.0	176.2	199.7	-14.5		
4-Toluidine	C ₇ H ₉ N	44.0	69.3	81.4	95.1	110.0	119.8	133.0	153.0	176.2	199.7	-29.5		
2-Tolyl isocyanate	C ₇ H ₇ N	41.0	68.0	82.0	96.7	113.5	123.8	136.7	157.4	180.4	203.3	-31.5		
2-Tolyl isocyanate	C ₇ H ₇ N	42.0	68.2	81.8	95.8	111.5	121.5	133.7	154.0	176.9	200.4	44.5		
4-Tolyl isocyanate	C ₇ H ₇ N	25.2	51.0	64.0	78.2	94.0	104.0	117.7	137.8	159.9	183.5			
Tribromomethylbenzene	C ₆ H ₅ Br	82.4	110.0	123.8	138.6	154.1	165.0	178.0	198.0	219.5	242.0	65.5		
1,1,2-Tribromobutane	C ₄ H ₇ Br ₂	18.5	45.0	58.0	72.1	87.8	97.5	110.2	130.0	151.4	174.0			
1,2,2-Tribromobutane	C ₄ H ₇ Br ₂	41.0	69.6	83.2	98.6	116.0	127.0	141.8	163.5	192.0	216.2			
2,2,3-Tribromobutane	C ₄ H ₇ Br ₂	38.2	66.0	79.0	94.6	111.6	122.2	136.3	157.8	182.2	204.5			
1,1,2,3-Tribromobutane	C ₄ H ₇ Br ₃	32.6	53.0	70.4	84.2	100.0	110.0	123.5	143.5	165.4	188.4	-26		
1,2,3,4-Tribromobutane	C ₄ H ₇ Br ₃	47.5	75.8	90.0	105.8	122.8	134.0	148.0	170.0	195.0	220.0	16.5		
Trichlorobenzene	C ₆ H ₃ Cl ₃	32.3	57.4	69.8	83.0	97.0	107.3	119.0	139.0	157.8	179.0	-22		
2,4,6-Trichlorophenol	C ₆ H ₃ Cl ₃ O	18.0	44.0	56.5	70.0	85.7	96.7	110.0	130.2	150.0	170.0			
Trichloroacetic acid	C ₂ HCl ₃ O ₂	95.2	126.1	142.0	158.0	177.4	188.0	203.0	225.2	250.6	276.3			
Trichloroacetyl bromide	C ₂ HCl ₃ OBr	51.0	76.0	88.2	101.8	116.3	125.9	137.8	155.4	175.2	195.4	57		
2,4,6-Trichloroaniline	C ₆ H ₃ Cl ₃ N	56.2	85.3	99.6	114.3	131.2	141.3	155.2	176.2	199.8	223.0			
1,2,3-Trichlorobenzene	C ₆ H ₃ Cl ₃	-7.4	+16.7	29.3	42.1	57.2	66.7	79.5	98.4	120.2	143.0			
1,2,4-Trichlorobenzene	C ₆ H ₃ Cl ₃	134.0	157.8	170.0	182.6	195.8	204.5	214.6	229.8	246.4	262.0	78		
1,3,5-Trichlorobenzene	C ₆ H ₃ Cl ₃	40.0	70.0	85.6	101.8	119.6	131.5	146.0	168.2	193.5	218.3	52.5		
1,2,3-Trichlorobutane	C ₄ H ₇ Cl ₃	38.4	63.6	74.8	88.0	102.4	111.7	123.8	142.0	161.8	183.0	17		
1,1,1-Trichloroethane	C ₂ HCl ₃	-10.5	27.2	40.0	55.0	71.6	82.0	96.2	118.0	143.0	169.0	63.5		
1,1,2-Trichloroethane	C ₂ HCl ₃	-32.0	-32.0	-21.9	-10.8	+1.6	8.5	20.0	36.2	54.6	74.1	-30.6		
1,1,2,3-Trichlorobutane	C ₄ HCl ₃	-24.0	-2.0	+8.3	21.6	35.2	44.0	55.7	73.5	93.0	113.9	-56.7		
Trichloroethylene	C ₂ HCl ₃	-43.8	-22.8	-12.4	-1.0	+11.9	20.0	31.4	48.0	67.0	86.7	-73		
2,4,5-Trichlorophenol	C ₆ H ₃ Cl ₃ O	-84.3	-67.6	-59.0	-49.7	-39.0	-32.3	-23.0	-9.1	+6.8	20.7			
2,4,6-Trichlorophenol	C ₆ H ₃ Cl ₃ O	72.0	102.1	117.3	134.0	151.5	162.5	178.0	201.5	226.5	251.8			
Tri-2-chlorophenylthiophosphine	C ₁₂ H ₇ Cl ₆ PS	76.5	105.9	120.2	135.8	152.2	163.5	177.8	199.0	222.5	246.0	62		
1,1,1-Trichloropropane	C ₃ HCl ₃	188.2	217.2	231.2	246.7	261.7	271.5	283.8	302.8	322.0	341.3	68.5		
1,2,3-Trichloropropane	C ₃ HCl ₃	-28.8	-7.0	+4.2	16.2	29.9	38.3	50.0	67.7	87.5	108.2	-77.7		
1,1,2-Trichloro-1,2,3-trichloroethane	C ₄ HCl ₃	-4.0	33.7	46.0	59.3	74.0	83.6	96.1	115.6	137.0	158.0	-14.7		
Trichloroethane	C ₂ HCl ₃	170.0	206.3	223.0	240.3	258.5	277.8	298.0	319.0	341.0	363.0	-35		
Trichloroacetic acid	C ₂ HCl ₃ O ₂	52.4	98.3	104.0	120.2	137.7	148.2	162.5	183.0	209.4	234.0	47.7		
Trichloromethylbenzene	C ₆ H ₅ Cl ₃	137.8	166.3	181.0	195.8	212.4	222.0	236.0	255.2	276.5	299.0	-6.2		
Trichlorophenylsilane	C ₆ H ₄ Cl ₃ Si	-1.5	+22.8	34.6	47.2	61.7	70.4	82.7	101.0	121.8	145.5	41		
1,2,4-Triethylbenzene	C ₉ H ₁₂	71.0	98.8	112.6	127.2	143.5	153.2	167.5	188.0	210.5	233.5			
1,3,4-Triethylbenzene	C ₉ H ₁₂	46.0	74.2	88.5	104.0	121.7	132.2	146.8	168.3	193.2	218.0			
Triethylborane	C ₆ H ₁₄ B	47.9	76.0	90.2	105.8	122.6	133.4	147.7	168.3	193.2	217.5			
Triethylcamphorane	C ₁₀ H ₁₈ B			-148.0	-140.6	-131.4	-125.2	-116.0	-101.0	-81.0	-56.2			
Triethylchloride	C ₆ H ₁₅ Cl	150.2	166.0	183.6	201.8	219.5	238.0	256.8	276.0	296.0	316.0	135		
Triethylmethylsilane	C ₉ H ₂₁ Si	107.0	138.7	144.0	171.1	190.4	202.5	217.8	242.2	267.5	294.0			
Triethylphenylsilane	C ₉ H ₁₉ Si	114.0	144.0	158.1	174.0	191.3	201.5	214.6	235.2	256.6	278.3			
Triethylthiophenylsilane	C ₉ H ₁₇ SiS	70.0	99.8	114.6	130.3	148.0	158.2	171.0	196.0	221.0	247.0			
Triethyl orthoformate	C ₃ H ₉ O ₃	73.7	104.8	120.2	137.7	155.7	166.0	180.4	204.0	235.0	262.0			
Triethylphosphine	C ₆ H ₁₅ P	+5.5	29.2	40.5	53.4	67.5	76.0	88.0	106.0	125.7	146.0			
Triethylthallium	C ₆ H ₁₅ Tl	39.6	67.8	82.1	97.8	115.7	125.3	141.6	163.7	187.0	211.0			
Triethoxyphenylsilane	C ₉ H ₁₇ OSi	+9.3	37.6	51.7	67.7	85.4	95.7	112.1	136.0	163.5	192.1	-63.0		
Trimethylthiophosphate	C ₃ H ₉ PS	-31.0	-9.7	+0.8	12.3	25.4	33.2	44.2	60.1	78.7	98.3			
2,2,5-Triethylthiophenylsilane	C ₉ H ₁₇ OSi	93.7	131.0	149.8	169.8	192.0	207.0	223.7	253.0	284.0	316.0			



Compound		Pressure, mm. Hg											Melting point, °C.
Name	Formula	1	5	10	20	40	60	100	200	400	760		
Temperature, °C.													
Trimethylacetyl (1,3-propanediol).....	C ₆ H ₁₂ O ₃	59.4	87.2	100.6	115.5	131.0	141.1	153.4	172.8	193.5	214.2		
1,2,4-Trimethyl-3-ethylbenzene.....	C ₁₁ H ₁₈	43.7	71.2	84.6	99.7	106.0	126.3	140.5	160.5	184.5	208.1		
1,3,5-Trimethyl-3-ethylbenzene.....	C ₁₁ H ₁₈	38.4	67.0	80.5	96.0	113.2	123.8	137.9	158.4	183.5	208.0		
2,2,4-Trimethylpentane.....	C ₈ H ₁₈	-29.0	-7.1	+3.9	16.8	29.5	36.1	49.9	67.0	88.2	109.0	-112.5	
2,3,3-Trimethylpentane.....	C ₈ H ₁₈	-36.5	-15.0	-4.3	+7.5	20.7	29.1	40.7	58.1	78.0	99.2	-107.3	
2,2,4-Trimethylpentane.....	C ₈ H ₁₈	-25.8	-3.9	+6.9	19.2	33.0	41.8	53.8	72.8	92.7	114.0	-101.5	
2,3,4-Trimethylpentane.....	C ₈ H ₁₈	-25.3	-4.1	+7.1	19.3	32.9	41.6	53.4	71.5	91.8	113.5	-109.2	
Trimethyl phosphite.....	C ₃ H ₉ O ₃ P	14.7	36.0	46.4	57.6	69.8	77.3	87.6	102.2	118.4	135.0		
2,4,5-Trimethylstyrene.....	C ₁₀ H ₁₄	26.0	53.7	67.8	83.0	100.0	110.0	124.0	145.0	167.0	192.7		
2,4,6-Trimethylstyrene.....	C ₁₀ H ₁₄	48.1	77.0	91.6	107.1	124.2	135.5	149.0	171.8	196.1	221.2		
Trimethylacetic anhydride.....	C ₆ H ₁₀ O ₃	37.5	65.7	79.7	94.8	111.8	122.5	136.8	157.8	182.3	207.0		
Triphenylmethane.....	C ₁₈ H ₁₅	53.5	82.6	97.4	113.8	131.0	142.2	156.5	179.8	205.5	231.0		
Triphenylphosphine.....	C ₁₈ H ₁₅ O ₃ P	169.7	188.4	197.0	206.8	215.5	221.2	228.4	239.7	249.0	259.2	95.4	
Tripropylacetyl.....	C ₉ H ₁₈ O ₃	193.5	230.4	249.8	269.7	290.3	305.2	322.5	349.8	379.2	413.5	49.4	
Tripropylacetyl monobutyl ether.....	C ₁₂ H ₂₂ O ₂	96.0	125.7	140.5	155.8	173.7	184.6	199.0	220.2	244.3	267.2		
Tripropylacetyl monoisopropyl ether.....	C ₁₂ H ₂₂ O ₂	101.5	131.6	147.0	161.8	179.8	190.2	204.4	224.4	247.0	269.5		
Triethyl phosphite.....	C ₆ H ₁₅ O ₃ P	82.4	112.4	127.3	143.7	161.4	173.2	187.6	209.7	232.8	256.4		
Undecane.....	C ₁₁ H ₂₄	154.6	184.2	198.0	213.2	229.7	250.0	262.2	271.0	292.7	313.0		
Undecanoic acid.....	C ₁₁ H ₂₀ O ₂	32.7	59.7	73.9	85.6	104.4	115.2	128.1	149.3	171.9	195.8	-25.6	
10-Undecenoic acid.....	C ₁₁ H ₂₀ O ₂	101.4	133.1	149.0	166.0	185.6	197.2	212.5	237.8	262.8	290.0	29.5	
Undecene-2-ol.....	C ₁₁ H ₂₂ O	114.0	142.8	156.3	172.0	188.7	199.5	213.5	232.8	254.0	275.0	24.5	
n-Valeric acid.....	C ₆ H ₁₂ O ₂	71.1	99.0	112.8	127.5	143.7	153.7	167.2	187.7	209.8	232.0		
iso-Valeric acid.....	C ₆ H ₁₂ O ₂	42.2	67.7	79.8	93.1	107.8	116.6	128.3	146.0	165.0	184.4	-34.5	
γ-Valerolactone.....	C ₆ H ₁₀ O ₂	34.5	59.6	71.3	84.0	98.0	107.3	118.9	136.2	155.2	175.1	-37.6	
Valeronitrile.....	C ₆ H ₁₁ N	37.5	65.8	79.8	95.2	101.9	122.4	136.5	157.7	182.3	207.5		
Vanillin.....	C ₈ H ₈ O	-6.0	+18.1	30.0	43.3	57.8	66.9	78.6	97.7	118.7	140.8		
Vinyl acetate.....	C ₄ H ₆ O ₂	107.0	138.4	154.0	170.5	188.7	199.8	214.5	237.5	260.0	285.0	81.5	
2-Vinylbenzole.....	C ₈ H ₈	-48.0	-28.0	-18.0	-7.0	+5.3	13.0	23.3	38.4	55.5	72.5		
3-Vinylbenzole.....	C ₈ H ₈	41.9	68.0	81.0	94.7	110.0	119.8	132.3	151.0	172.1	194.0		
4-Vinylbenzole.....	C ₈ H ₈	43.4	69.9	83.0	97.2	112.5	122.3	135.3	154.0	175.8	197.5		
Vinyl chloride (1-chloroethylene).....	C ₂ H ₃ Cl	45.2	72.0	85.7	100.0	116.0	128.1	139.7	159.0	182.0	204.5		
acrylonitrile.....	C ₃ H _{3.5} N	-105.6	-90.8	-83.7	-75.7	-66.8	-61.1	-53.2	-41.3	-28.0	-13.8	-153.7	
fluoride (1-fluoroethylene).....	C ₂ H ₃ F	-51.0	-30.7	-20.3	-9.0	+3.8	11.2	22.8	38.7	58.3	78.5	-82	
vinylidene chloride (1,1-dichloroethylene).....	C ₂ H ₂ Cl ₂	-149.3	-138.0	-132.2	-125.4	-118.0	-113.0	-106.2	-95.4	-84.0	-72.2	-160.5	
4-Vinylphenetole.....	C ₁₀ H ₁₂ O	-77.2	-60.0	-51.2	-41.7	-31.1	-24.0	-15.0	-1.0	+14.8	31.7	-122.5	
2-Xenyl dichlorophosphate.....	C ₁₂ H ₉ Cl ₂ PO	64.0	91.7	105.6	120.3	136.3	146.4	159.8	180.0	202.0	225.0		
2,4-Xyldichyde.....	C ₈ H ₁₀ O	138.2	171.1	187.0	205.0	223.8	236.0	251.5	275.5	301.5	328.5		
2-Xylene (2-xylene).....	C ₈ H ₁₀	59.0	85.9	99.0	114.0	129.7	139.0	152.2	172.3	194.1	215.5	75	
3-Xylene (3-xylene).....	C ₈ H ₁₀	-3.8	+20.2	32.1	45.1	59.5	68.8	81.3	100.2	121.7	144.4	-25.2	
4-Xylene (4-xylene).....	C ₈ H ₁₀	-6.9	+16.8	28.3	41.1	55.3	64.4	76.6	95.5	116.7	139.1	-47.9	
2,4-Xyldine.....	C ₈ H ₁₀ N	-8.1	+15.5	27.3	40.1	54.4	63.5	75.9	94.6	115.9	138.3	+13.3	
2,6-Xyldine.....	C ₈ H ₁₀ N	52.6	77.8	93.0	107.6	123.8	133.7	146.8	166.4	188.3	211.5		
		44.0	72.6	87.0	102.7	120.2	131.5	146.0	168.0	193.7	217.9		

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EXHIBIT 4-2

VAPOR PRESSURES OF INORGANIC MATERIALS (9)

Compound		Pressure, mm. Hg										Melting point, °C.	
Name	Formula	1	5	10	20	40	60	100	200	400	760		
Temperature, °C.													
Arsenic	trichloride	Al	1254	1421	1487	1535	1635	1684	1749	1844	1947	2054	620
boron	trichloride	AlBr ₃	-52.2	-42.9	-32.5	-20.9	-13.4	-3.9	+11.2	23.1	45.9	64	-64
boron	trichloride	AlBr ₃	81.3	103.8	118.0	134.0	150.6	161.7	176.1	199.8	227.0	254.3	97.4
boron	trichloride	AlCl ₃	100.0	116.4	123.8	131.8	139.9	145.4	152.0	161.8	171.6	180.2	192.4
boron	trichloride	AlF ₃	1234	1293	1324	1350	1378	1399	1422	1457	1496	1537	1040
boron	trichloride	AlI ₃	173.0	207.7	225.6	244.2	265.0	277.8	294.5	322.0	354.0	385.5	2090
boron	trichloride	Al ₂ O ₃	2148	2306	2385	2445	2549	2599	2665	2746	2874	2977	2090
boron	trichloride	NH ₃	-109.1	-97.5	-91.9	-85.6	-79.2	-74.3	-68.4	-62.0	-55.4	-48.4	-77.7
boron	trichloride	ND ₃						-74.0	-67.4	-60.0	-53.4	-46.4	-74.0
boron	trichloride	NH ₄ Br	196.5	234.5	251.9	270.8	290.0	301.8	320.0	345.5	370.8	396.0	520
boron	trichloride	NH ₄ CO ₃	-26.1	-10.4	-2.9	+3.5	14.0	19.4	26.7	37.2	48.0	58.5	56
boron	trichloride	NH ₄ Cl	160.4	193.8	209.8	226.1	245.8	266.2	271.5	285.2	316.5	357.0	320
boron	trichloride	NH ₄ CN	-50.6	-35.7	-28.0	-20.9	-12.6	-7.4	-0.5	+9.6	20.5	31.7	36
boron	trichloride	NH ₄ HS	-51.1	-36.0	-28.7	-20.8	-12.5	-7.6	0.0	+10.5	21.8	33.3	36
boron	trichloride	NH ₄ I	210.9	247.0	263.5	282.8	302.8	316.0	331.8	355.0	381.0	404.9	630.5
Antimony	trichloride	Sb	856	984	1073	1164	1258	1356	1457	1562	1674	1792	260.5
boron	trichloride	SbBr ₃	93.9	126.0	142.7	158.3	177.4	188.1	203.5	225.7	250.2	275.0	96.6
boron	trichloride	SbCl ₃	49.2	71.4	85.2	100.6	117.8	128.3	143.3	165.9	192.2	219.0	73.4
boron	trichloride	SbI ₃	22.7	48.0	61.8	75.8	91.0	101.0	114.1	133.8	160.5	188.0	2.8
boron	trichloride	SbO ₂	163.6	203.8	223.5	244.8	267.8	282.5	303.5	333.8	368.5	401.0	167
boron	trichloride	SbO ₃	574	626	666	729	812	873	957	1085	1242	1423	656
Argon		A	-218.2	-213.9	-210.9	-207.9	-204.9	-202.9	-200.5	-195.6	-190.6	-185.6	-189.2
Arsenic	trichloride	As	372	416	437	459	483	498	518	548	579	610	814
boron	trichloride	AsBr ₃	41.6	70.6	85.2	101.5	118.7	130.0	145.2	167.7	193.6	220.0	-18
boron	trichloride	AsCl ₃	-11.4	+11.7	+23.5	36.0	50.0	58.7	70.9	89.2	109.7	130.3	-5.9
boron	trichloride	AsF ₃	-117.8	-108.0	-103.1	-98.0	-92.4	-86.5	-80.3	-73.8	-64.0	-52.8	-79.8
boron	trichloride	AsF ₅	212.5	242.6	259.7	279.2	299.2	310.3	324.3	370.0	412.2	457.2	312.8
boron	trichloride	AsI ₃	-142.6	-130.8	-124.7	-117.7	-110.2	-104.6	-97.2	-88.0	-75.2	-62.1	-116.3
Barium	trichloride	Ba		984	1049	1120	1195	1240	1301	1403	1518	1638	1823
boron	trichloride	Ba(BH ₄) ₂	+1.0	19.8	23.1	36.8	46.2	51.7	58.6	69.0	79.7	90.0	123
boron	trichloride	BaBr ₂	289	323	342	361	379	390	403	427	451	474	490
boron	trichloride	BaCl ₂	291	328	346	365	384	395	411	435	461	487	495
boron	trichloride	BaI ₂	283	322	341	361	382	394	411	435	461	487	495
Bismuth	trichloride	Bi	1021	1099	1136	1177	1217	1240	1271	1319	1370	1420	271
boron	trichloride	BiBr ₃		281	282	305	327	340	360	372	425	461	218
boron	trichloride	BiCl ₃		242	254	287	311	324	345	372	405	441	230
boron	trichloride	BiI ₃											
boron	trichloride	B ₂ H ₆	-93.5	-75.3	-66.3	-56.4	-45.4	-38.2	-29.0	-15.4	0.0	+16.3	-104.2
boron	trichloride	B ₂ H ₄ CO	-139.2	-127.3	-121.1	-114.1	-106.6	-101.9	-95.3	-85.5	-74.8	-64.0	-137.0
boron	trichloride	B ₂ H ₄ H ₂	-63.0	-45.0	-35.3	-25.0	-13.2	-5.8	+4.0	18.5	34.3	50.6	-58.2
boron	trichloride	B ₂ H ₆	60.0	80.8	90.2	100.0	112.4	127.8	142.3	163.8	188.5	216.1	99.6
boron	trichloride	B ₂ H ₄	-159.7	-149.5	-144.3	-138.5	-131.6	-127.7	-120.9	-111.2	-99.6	-88.1	-169
boron	trichloride	B ₂ H ₂	-49.4	-30.7	-20.0	-8.0	-0.4	+9.6	24.6	40.8	53.1	63.0	-47.0
boron	trichloride	B ₂ H ₄	-50.2	-29.9	-19.9	-9.2	+2.7	10.2	20.1	34.8	51.2	67.0	-119.9
boron	trichloride	B ₂ H ₄	-50.9	-73.1	-64.3	-54.8	-44.3	-37.4	-28.1	-14.0	+0.8	15.1	-45
boron	trichloride	B ₂ H ₄	-41.4	-20.4	-10.1	+1.5	14.0	22.1	33.5	50.3	70.0	91.7	-107
boron	trichloride	B ₂ H ₄	-91.5	-75.2	-66.9	-57.9	-47.0	-41.2	-32.4	-18.9	-5.6	+12.7	-126.8
boron	trichloride	BF ₃	-154.6	-145.4	-141.3	-136.4	-131.0	-127.6	-123.0	-115.9	-108.3	-100.7	-7.3
boron	trichloride	Br ₂	-48.7	-32.8	-25.0	-16.8	-8.0	+0.4	+9.3	24.3	41.0	58.2	-61.4
boron	trichloride	Br ₂	-69.3	-51.0	-41.9	-32.0	-21.0	-14.0	-4.5	+9.9	25.7	40.4	-320.9
Calcium	trichloride	Ca	394	455	484	516	553	578	611	658	711	765	851
boron	trichloride	CaCl ₂		618	656	695	736	762	797	847	903	967	550
boron	trichloride	CaF ₂	1112	1231	1286	1344	1400	1456	1496	1561	1651	1751	520
boron	trichloride	CaI ₂	416	481	512	546	584	608	640	688	742	795	383
boron	trichloride	CaO	1000	1100	1169	1230	1287	1341	1391	1484	1599	1721	851
Carbon	graphite	C	3386	3828	3946	4059	4196	4273	4373	4516	4660	4827	-57.5
boron	trichloride	CO ₂	-134.3	-124.4	-119.5	-114.4	-108.6	-104.8	-100.2	-93.0	-85.7	-78.2	-110.8
boron	trichloride	CO ₂	-73.8	-54.3	-44.7	-34.3	-22.5	-15.3	-5.1	+10.4	25.0	46.5	-203.0
boron	trichloride	CO ₂	-222.0	-217.2	-215.0	-212.8	-210.0	-208.1	-205.7	-201.3	-196.3	-191.3	-138.8
boron	trichloride	CO ₂	-117.1	-102.3	-95.0	-86.3	-76.4	-61.7	-49.8	-35.6	-21.9	-9.9	-73.2
boron	trichloride	CO ₂	-132.4	-119.8	-113.3	-106.0	-98.3	-93.0	-85.9	-75.0	-62.7	-49.9	-0.4
boron	trichloride	CO ₂	-47.3	-26.5	-16.0	-4.4	+8.6	17.0	28.3	45.7	65.2	83.6	-10.5
boron	trichloride	CO ₂	14.0	41.2	54.9	69.3	85.6	96.0	109.9	130.8	163.5	199.5	-22.6
boron	trichloride	CO ₂	-50.0	-30.0	-19.6	-8.2	+4.3	12.3	23.0	38.3	57.8	76.7	-183.7
boron	trichloride	CO ₂	-184.6	-174.1	-169.3	-164.3	-158.6	-155.4	-150.7	-143.6	-135.5	-127.7	28.5
Cesium	trichloride	Cs	279	341	373	409	449	474	509	561	624	690	636
boron	trichloride	CsBr	748	838	857	938	993	1026	1072	1140	1221	1300	646
boron	trichloride	CsCl	744	837	854	934	989	1023	1069	1139	1217	1300	646
boron	trichloride	CsF	712	798	844	893	947	990	1023	1072	1170	1251	683
boron	trichloride	CsI	738	828	873	923	976	1009	1055	1129	1200	1280	683
Chlorine	trichloride	Cl ₂	-118.0	-106.7	-101.4	-93.3	-84.5	-79.0	-71.7	-60.2	-47.3	-33.8	-100.7
boron	trichloride	ClF	-143.4	-139.0	-134.3	-128.8	-125.3	-120.8	-114.4	-107.0	-100.5	-93.0	-63
boron	trichloride	ClF ₃	-80.4	-71.8	-62.3	-51.3	-44.1	-34.7	-20.7	-4.9	+11.5	+22.2	-116
boron	trichloride	ClO ₂	-90.5	-81.6	-73.1	-64.3	-54.3	-48.0	-39.4	-26.5	-12.5	+2.2	-59
boron	trichloride	ClO ₂			-59.0	-51.2	-42.8	-37.2	-29.4	-17.8	-4.0	+11.1	-91
boron	trichloride	ClO ₂	-45.3	-23.6	-13.2	-2.1	+10.3	+18.2	29.1	44.6	62.2	73.8	-80
Chlorosulfonic acid		HSO ₃ Cl	32.0	53.5	64.0	75.3	87.4	95.2	105.3	120.0	136.1	151.0	-80
Chromium	trichloride	Cr	1616	1768	1845	1928	2013	2067	2139	2243	2361	2482	1615
boron	trichloride	Cr(CO) ₃	36.0	58.0	68.3	79.5	91.2	98.5	108.0	121.8	137.2	151.0	-11
boron	trichloride	Cr(CO) ₃ NO	-18.4	+3.2	13.8	25.7	38.5	46.7	58.0	75.2	95.2	117.1	73.5
Cobalt	trichloride	Co											
boron	trichloride	Co(CO) ₃ NO											
Columbium	trichloride	Cb											
Copper	trichloride	Cu	1625	1793	1879	1970	2067	2127	2207	2325	2465	2595	1083
boron	trichloride	CuBr	571	718	777	844	897	951	995	1052	1119	1195	504
boron	trichloride	CuCl	546	693	752	818	868	910	957	1017	1077	1149	422
boron	trichloride	CuI		610	656	716	736	736	736	736	736	736	605
Cyanogen	trichloride	CN ₂	-91.8	-81.2	-76.8	-70.1	-62.7	-57.9	-51.8	-42.6	-33.4	-24.0	-54
boron	trichloride	CNBr	-35.7	-18.3	-10.0	-1.0	+3.6	14.7	22.6	33.8	46.0	61.5	-9.4
boron	trichloride	CNCl	-76.7	-61.4	-53.8	-46.1	-37.5	-32.1	-21.9	-13.1	-2.3	+12.1	-5.5
boron													

* Compiled from the extended tables published by D. R. Stull in *Ind. Eng. Chem.*, 33, 517 (1947).

Compound	Name	Formula	Pressure, mm. Hg										Melting point, °C.
			1	5	10	20	40	60	100	200	400	760	
Temperature, °C.													
Deuterium cyanide.....	DCN		-68.9	-54.0	-46.7	-38.8	-30.1	-21.7	-17.5	-5.4	+10.0	26.2	-12
Fluorine.....	F ₂		-223.0	-216.9	-214.1	-211.0	-207.7	-205.6	-202.7	-198.3	-193.2	-187.9	-223
Fluoric acid.....	FO		-196.1	-186.6	-182.3	-177.8	-173.0	-170.0	-165.8	-159.0	-151.9	-144.4	-223.9
Germanium bromide.....	GeBr ₄			43.3	56.8	71.8	88.1	98.0	113.2	135.4	161.6	189.0	26.1
chloride.....	GeCl ₄		-45.0	-24.9	-15.0	-4.1	+4.0	16.2	27.5	44.4	63.8	84.0	-49.5
iodide.....	GeI ₄		-163.0	-151.0	-145.3	-139.2	-131.6	-124.7	-120.3	-111.2	-100.2	-88.9	-165
Trichlorogermine.....	GeCl ₃		-41.3	-22.3	-13.0	-3.0	+4.8	16.2	26.5	41.4	58.3	75.0	-71.1
Tetramethylgermane.....	Ge(CH ₃) ₄		-73.2	-54.6	-45.2	-35.0	-23.4	-16.2	-6.3	+4.8	26.0	44.0	-88
Digermene.....	Ge ₂ H ₆		-88.7	-69.8	-60.1	-49.9	-38.2	-30.7	-20.3	-4.7	+13.3	31.5	-109
Trigermene.....	Ge ₃ H ₈		-36.9	-12.8	-0.9	+11.8	26.3	35.5	47.9	67.0	88.6	110.8	-105.6
Gold.....	Au		1869	2059	2154	2254	2343	2431	2521	2657	2807	2966	1063
Helium.....	He		-271.7	-271.5	-271.3	-271.1	-270.7	-270.6	-270.3	-269.8	-269.3	-268.6	-279.1
para-Hydrogen.....	H ₂		-253.3	-261.9	-261.3	-260.4	-259.6	-259.6	-259.3	-258.7	-258.3	-257.5	-259.1
Hydrogen bromide.....	HBr		-138.8	-127.4	-121.8	-115.4	-108.3	-103.8	-97.7	-88.1	-78.0	-66.5	-137.0
chloride.....	HCl		-150.6	-140.7	-135.6	-130.0	-123.8	-119.4	-114.0	-105.2	-95.3	-84.8	-114.3
cyanide.....	HCN		-71.0	-55.3	-47.7	-39.7	-30.9	-25.1	-17.8	-5.3	+10.2	26.8	-15.3
fluoride.....	HF		-77.7	-74.7	-65.8	-56.0	-45.0	-37.9	-28.2	-13.2	+2.5	18.7	-83.7
iodide.....	HI		-122.3	-109.6	-102.3	-94.5	-85.6	-79.8	-72.1	-60.3	-48.3	-35.1	-110.9
oxide (white).....	H ₂ O		-17.3	+1.2	11.2	22.1	34.0	41.3	51.4	66.5	83.0	100.0	0.0
sulfide.....	H ₂ S		-134.3	-122.4	-116.3	-109.7	-102.3	-97.9	-91.4	-82.3	-71.8	-60.4	-85.5
disulfide.....	H ₂ S ₂		-43.2	-24.4	-15.2	-5.1	+4.0	12.8	22.0	35.3	49.6	64.0	-89.7
selenide.....	H ₂ Se		-115.3	-103.4	-97.9	-91.8	-84.7	-80.2	-74.2	-65.2	-53.6	-41.1	-64
telluride.....	H ₂ Te		-96.4	-82.4	-75.4	-67.8	-59.1	-53.7	-45.7	-32.4	-17.2	-2.0	-49.0
Iodine.....	I ₂		38.7	62.2	73.2	84.7	97.5	105.4	116.3	137.3	159.8	183.0	112.9
heptafluoride.....	IF ₇		-87.0	-70.7	-63.0	-54.5	-45.3	-39.4	-31.9	-20.7	-8.3	+4.0	5.5
Iron.....	Fe		1767	1957	2059	2125	2224	2283	2360	2475	2605	2755	1535
pentacarbonyl.....	Fe(CO) ₅			-6.5	+4.6	16.7	30.3	39.1	50.3	68.0	86.1	105.0	-21
Iron chloride.....	FeCl ₃		194.0	221.8	237.0	253.0	268.8	283.7	298.5	318.0	339.0	364.0	304
Iron fluoride.....	FeF ₃			700	737	770	805	842	881	920	959	1000	1028
Lead.....	Pb		-199.3	-191.3	-187.2	-182.9	-178.4	-175.7	-171.8	-165.9	-159.0	-152.0	-156.7
bromide.....	PbBr ₂		513	578	610	646	686	711	745	796	856	914	373
chloride.....	PbCl ₂		547	615	648	684	725	750	784	833	893	954	501
fluoride.....	PbF ₂			861	904	950	1003	1036	1080	1144	1219	1295	855
iodide.....	PbI ₂		479	540	571	605	644	668	701	750	807	872	402
oxide.....	PbO		943	1039	1085	1134	1189	1222	1265	1330	1402	1472	890
sulfide.....	PbS		852	928	975	1005	1040	1074	1108	1160	1221	1281	1114
Lithium.....	Li		723	828	881	940	1003	1042	1097	1178	1275	1372	186
bromide.....	LiBr		748	840	888	959	994	1028	1076	1147	1225	1310	547
chloride.....	LiCl		783	880	932	987	1045	1081	1129	1205	1290	1382	614
fluoride.....	LiF		1047	1156	1211	1270	1333	1372	1425	1505	1591	1681	870
iodide.....	LiI		723	802	841	885	927	955	993	1049	1110	1171	444
Magnesium.....	Mg		621	702	743	789	838	868	909	967	1034	1107	431
chloride.....	MgCl ₂		778	877	930	988	1050	1088	1142	1223	1316	1418	712
Mercury.....	Hg		1292	1434	1505	1583	1666	1729	1792	1900	2029	2151	1260
Mercuric bromide.....	HgBr ₂		126.2	164.8	184.0	204.6	228.8	247.0	261.7	290.7	325.0	357.0	-38.9
chloride.....	HgCl ₂		136.5	165.3	179.8	194.3	211.5	221.8	237.8	262.7	290.0	319.0	237
iodide.....	HgI ₂		157.5	169.2	204.5	220.0	238.2	249.0	261.8	291.0	324.2	354.0	259
Molybdenum.....	Mo		3102	3393	3535	3690	3859	3964	4109	4322	4553	4804	2622
hexafluoride.....	MoF ₆		-65.5	-49.0	-40.8	-32.0	-22.1	-16.2	-8.0	+4.1	17.2	36.0	17
oxide.....	MoO ₃		734	785	814	851	892	917	955	1014	1082	1151	795
Neon.....	Ne		-257.3	-255.5	-254.6	-253.7	-252.6	-251.9	-251.0	-249.7	-248.1	-246.0	-248.7
Nickel.....	Ni		1810	1979	2057	2143	2234	2289	2364	2475	2605	2755	1452
carbonyl.....	Ni(CO) ₄			721	759	789	821	840	856	904	945	987	1001
chloride.....	NiCl ₂		671	721	759	789	821	840	856	904	945	987	1001
Nitrogen.....	N ₂		-226.1	-221.3	-219.1	-216.8	-214.0	-212.3	-209.7	-205.6	-200.9	-195.8	-210.0
Nitric oxide.....	NO		-184.5	-180.6	-178.2	-175.3	-171.7	-168.9	-166.0	-162.3	-158.8	-151.7	-161.0
Nitrogen dioxide.....	NO ₂		-55.6	-42.7	-36.7	-30.4	-23.9	-19.9	-14.7	-5.0	+8.0	21.0	-9.3
Nitrogen pentoxide.....	N ₂ O ₅		-36.8	-23.0	-16.7	-10.0	-2.9	+1.8	7.4	15.6	24.4	32.4	30
Nitrous oxide.....	N ₂ O		-143.4	-133.4	-128.7	-124.0	-118.3	-114.9	-110.3	-103.6	-96.2	-85.5	-90.9
Nitroxy chloride.....	NOCl			-60.2	-54.2	-46.3	-37.9	-28.2	-17.8	-6.3	+10.2	26.8	-15.3
fluoride.....	NOF		-132.0	-120.3	-114.3	-107.8	-100.3	-95.7	-88.8	-79.2	-68.2	-56.0	-134
Osmium tetroxide (yellow).....	OsO ₄		3.2	22.0	31.3	41.0	51.7	59.4	71.5	89.5	109.3	130.0	56
(white).....	OsO ₄		-5.6	+15.6	26.0	37.4	50.5	59.4	71.5	89.5	109.3	130.0	56
Oxygen.....	O ₂		-219.1	-213.4	-210.6	-207.5	-204.1	-201.9	-198.8	-194.0	-188.8	-183.1	-218.7
Ozone.....	O ₃		-180.4	-168.6	-163.2	-157.2	-150.7	-146.7	-141.0	-132.6	-122.5	-111.1	-251
Phosphorus.....	P		-92.9	-77.0	-69.3	-60.3	-50.3	-44.0	-35.6	-22.3	-7.6	+8.3	-104
Phosphorus (yellow).....	P		76.6	111.2	128.0	146.2	166.7	179.8	197.3	222.7	251.0	280.0	44.1
(violet).....	P		237	271	287	306	323	334	349	370	391	417	590
tribromide.....	PBr ₃		7.8	34.4	47.8	62.4	79.0	89.8	103.6	125.2	149.7	175.3	-40
trichloride.....	PCl ₃		-51.6	-31.5	-21.3	-10.2	+2.3	10.2	21.0	37.6	56.9	74.2	-111.8
pentachloride.....	PCL ₅		55.5	74.0	83.2	92.5	102.5	108.3	117.0	131.3	147.2	162.0	-132.5
Phosphine.....	PH ₃		-89.7	-78.5	-70.0	-60.0	-50.0	-40.0	-30.0	-20.0	-10.0	0.0	-132.5
Phosphonium bromide.....	PH ₄ Br		-43.7	-28.5	-21.2	-13.3	-5.0	+0.3	7.4	17.6	28.0	38.3	-38.5
chloride.....	PH ₄ Cl		-91.0	-79.6	-74.0	-68.0	-61.5	-57.3	-52.0	-44.0	-35.4	-27.0	-38.5
iodide.....	PH ₄ I		-25.7	-9.0	-1.1	+7.3	16.1	21.9	29.3	39.9	51.6	62.3	-38.5
Phosphorus trioxide.....	P ₂ O ₃			39.7	53.0	67.8	84.0	94.2	108.3	129.0	150.3	173.1	22.5
pentoxide.....	P ₂ O ₅		384	424	442	462	481	493	510	532	556	591	569
oxychloride.....	POCl ₃				2.0	13.6	27.3	35.8	47.4	65.0	84.3	105.1	2
thiochloride.....	PSbBr ₃		-30.0	-72.4	-83.6	-95.5	-108.0	-116.0	-125.3	-141.6	-157.8	-175.0	58
thiochloride.....	PSCL ₃		-18.3	-4.6	16.1	29.0	42.7	51.8	63.8	82.0	102.3	124.0	-2.2
Platinum.....	Pt		2730	3007	3146	3302	3469	3574	3714	3923	4169	4407	1755
Potassium.....	K		341	408	443	483	524	550	586	643	708	774	62.3
bromide.....	KBr		795	892	940	994	1050	1087	1137	1212	1297	1383	730
chloride.....	KCl		821	919	968	1020	1078	1115	1164	1239	1322	1407	790
fluoride.....	KF		885	988	1039	1096	1156	1193	1245	1325	1411	1502	830
hydroxide.....	KOH		719	814	863	918	976	1013	1064	1142	1233	1327	380
iodide.....	KI		745	840	887	938	995	1030	1080	1152	1238	1324	723
Radium.....	Ra		-144.2	-132.4	-126.3	-119.2	-111.3	-106.2	-99.0	-87.7	-75.0	-61.8	-71
Rhenium heptoxide.....	ReO ₇		212.5	237.5	258.0	261.0	272.0	280.0	289.0	307.0	336.0	362.4	296

Compound	Name	Formula	Pressure, mm. Hg										Melting point, °C.
			1	5	10	20	40	60	100	200	400	760	
			Temperature, °C.										
Rubidium	Rb		297	358	509	423	459	483	514	543	620	679	38.3
bromide	RbBr		781	876	923	975	1031	1066	1114	1186	1267	1332	682
chloride	RbCl		792	887	937	990	1047	1084	1133	1207	1287	1351	715
fluoride	RbF		921	982	1016	1052	1096	1123	1168	1239	1322	1400	740
iodide	RbI		748	839	884	935	991	1026	1072	1141	1223	1304	740
Selenium	Se		356	413	442	473	506	527	554	584	657	689	217
dioxide	SeO ₂		157.0	187.7	232.5	217.5	234.1	244.6	258.0	277.0	297.7	317.9	348
hexafluoride	SeF ₆		-118.4	-105.2	-94.9	-82.3	-64.7	-50.0	-37.9	-24.8	-15.2	-4.8	-34.7
oxychloride	SeOCl ₂		34.0	59.4	71.9	81.2	96.0	106.5	118.0	134.0	151.7	164.0	8.5
tetrachloride	SeCl ₄		74.0	96.3	107.4	118.1	130.1	137.0	147.5	161.0	176.4	191.5	
Silicon	Si		1724	1835	1860	1942	2000	2036	2083	2151	2220	2287	1420
dioxide	SiO ₂												1710
tetrachloride	SiCl ₄		-63.4	-44.1	-34.4	-24.0	-12.1	-4.8	+5.4	21.0	38.4	56.0	-68.0
trichlorosulfuric acid	SiF ₆		-144.0	-124.0	-130.4	-125.9	-120.0	-117.5	-113.3	-108.7	-104.0	-99.0	-120.0
iodosilane	SiF ₄ I ₂		-92.6	-76.4	-68.3	-59.0	-48.0	-42.2	-35.2	-27.9	-19.3	-10.0	-57.0
dichlorosilane	SiH ₂ Cl ₂			-53.0	-47.7	-33.4	-21.0	-14.3	-4.4	+10.7	27.9	45.4	-1.0
disilane	(SiH ₄) ₂ O		-112.5	-95.0	-88.2	-79.0	-70.4	-64.2	-55.9	-45.9	-35.3	-25.4	-144.2
trisilane	(SiH ₄) ₃ N		-68.9	-49.7	-40.0	-30.0	-16.9	-9.0	+1.4	17.0	35.3	53.1	-17.2
tetrasilane	(SiH ₄) ₄		-27.7	-6.2	+4.3	15.8	28.4	36.6	47.4	63.0	81.7	100.0	-103.7
octachlorosilane	Si ₂ Cl ₈		46.5	74.7	79.3	84.2	91.5	99.2	107.4	116.2	125.4	134.0	-35.2
hexachlorodisilane	Si ₂ Cl ₆		-3.0	17.8	29.4	41.5	53.3	63.0	75.4	88.2	102.0	115.0	-1.2
tetrachlorosilane	SiCl ₄		-4.0	27.4	38.0	51.5	65.0	75.4	88.2	102.0	115.0	134.0	-35.2
trichlorosilane	SiH ₃ Cl		-30.5	-8.0	+3.4	14.0	30.0	39.2	51.4	63.0	75.4	88.2	-1.2
trifluorosilane	SiF ₃ H		-80.7	-62.6	-53.4	-43.0	-32.9	-23.8	-14.6	-4.0	+14.3	31.8	-75.5
dichlorosilane	SiH ₂ Cl ₂		-152.0	-142.7	-138.2	-132.9	-127.5	-123.7	-118.7	-113.3	-108.7	-104.0	-120.0
monochlorosilane	SiH ₃ Cl		-40.9	-40.0	-29.4	-18.0	-5.2	+3.2	14.1	31.4	48.7	65.0	-51.4
monochlorosilane	SiH ₃ Cl		-146.7	-136.0	-130.4	-124.3	-117.6	-110.3	-102.3	-93.3	-83.4	-73.0	-70.2
monochlorosilane	SiH ₃ Cl		-117.8	-85.7	-77.3	-68.3	-57.8	-51.1	-42.3	-32.4	-22.4	-13.3	-4.4
monochlorosilane	SiH ₃ Cl		-133.0	-145.3	-141.2	-136.3	-130.8	-127.2	-122.4	-115.2	-106.2	-96.0	-85.9
tribromodichlorosilane	SiBr ₂ Cl ₂		-44.1	-25.4	-15.1	-3.7	+9.2	17.4	28.6	45.7	64.0	83.0	-32.5
dichlorodifluorosilane	SiF ₂ Cl ₂		-124.7	-110.5	-102.9	-94.5	-85.0	-78.6	-70.3	-60.0	-49.0	-38.0	-139.7
trifluorodichlorosilane	SiF ₃ Cl		-144.0	-133.0	-127.0	-120.5	-112.6	-104.2	-95.7	-86.0	-75.0	-64.0	-70.5
hexafluorodichlorosilane	SiF ₆		-81.0	-68.0	-63.1	-57.0	-50.4	-43.7	-37.1	-30.4	-23.7	-17.0	-142
dichlorodifluorosilane	SiF ₂ Cl ₂		-86.3	-68.4	-59.0	-48.0	-37.0	-26.0	-15.0	-4.0	+6.0	+15.0	-112.3
monochlorodifluorosilane	SiF ₃ H		-65.2	-45.5	-35.6	-24.5	-12.0	-4.7	+6.3	23.0	40.0	59.5	-99.3
silane	SiH ₄		-179.3	-140.6	-163.0	-154.9	-146.3	-140.5	-131.4	-122.0	-111.5	-101.5	-185
disilane	SiH ₆		-114.0	-99.3	-91.4	-82.7	-72.8	-64.4	-57.5	-49.0	-40.0	-31.0	-132.6
Silver	Ag		1357	1500	1575	1658	1743	1795	1865	1950	2050	2170	960.5
chloride	AgCl		912	1019	1074	1134	1200	1242	1297	1379	1467	1554	655
iodide	AgI		820	927	983	1045	1111	1152	1210	1297	1400	1506	552
Sodium	Na		439	511	549	589	633	662	701	758	823	892	97.5
bromide	NaBr		806	903	952	1005	1060	1099	1148	1220	1304	1392	735
chloride	NaCl		865	967	1017	1072	1131	1169	1220	1296	1379	1463	820
cyanide	NaCN		817	928	983	1046	1115	1156	1214	1302	1404	1497	564
fluoride	NaF		1077	1186	1240	1300	1365	1405	1455	1531	1617	1704	992
hydride	NaOH		759	843	897	953	1017	1057	1111	1192	1286	1378	318
iodide	NaI		767	857	903	952	1005	1039	1085	1150	1225	1304	651
Strontium	Sr		847	898	953	1018	1057	1111	1192	1285	1384	1480	800
Strontium oxide	SrO		2068	2198	2262	2333	2410						2430
Sulfur	S		183.8	223.0	243.0	264.7	288.5	305.5	327.2	359.6	444.6	512.8	112.8
monochloride	SF ₆		-7.4	+15.7	27.5	40.0	54.1	63.2	75.3	93.5	115.4	138.0	-80
Sulfuryl chloride	SF ₄		-132.7	-120.4	-114.7	-108.4	-101.5	-96.0	-90.9	-82.3	-72.4	-63.5	-30.2
Sulfur dioxide	SO ₂		-35.1	-24.0	-13.4	-1.0	+7.2	17.8	33.7	51.3	70.2	90.2	-54.1
bromide (α)	SO ₃		-95.5	-85.0	-76.0	-69.7	-60.5	-54.6	-48.9	-43.0	-37.0	-31.0	-16.8
bromide (β)	SO ₃		-39.0	-25.7	-16.5	-9.1	-1.0	+4.0	10.5	20.5	32.6	44.8	32.3
bromide (γ)	SO ₃		-34.0	-19.2	-12.3	-4.9	+3.2	8.0	14.3	25.7	37.6	49.0	62.1
Tellurium	Te		539	665	693	733	789	838	910	997	1087	1187	432
chloride	TeCl ₄		-111.3	-96.8	-92.4	-86.0	-78.8	-70.9	-62.9	-54.8	-46.7	-38.6	-204
fluoride	TeF ₆		825	931	983	1040	1103	1145	1196	1274	1364	1457	3095
Thallium	Tl		490	522	559	598	631	655	705	759	819	880	460
Thallous bromide	TlBr		487	517	550	589	612	645	694	748	807	870	430
chloride	TlCl		440	502	531	567	607	631	663	712	763	825	440
iodide	TlI		-6.7	+18.4	31.0	44.1	58.8	68.5	80.4	95.0	112.2	139.5	-52.2
Thionyl bromide	SOBr ₂		-52.9	-32.4	-21.9	-10.5	+2.2	10.4	21.4	37.9	56.5	75.4	-104.5
Thionyl chloride	SOCl ₂		1492	1634	1703	1777	1855	1903	1966	2063	2169	2276	231.9
Stannous bromide	SnBr ₂		318	366	391	420	450	467	493	533	577	623	246.0
Stannous chloride	SnCl ₂		-22.7	-1.0	+10.0	22.0	35.2	43.5	54.7	72.0	92.1	113.0	-30.2
Stannic bromide	SnBr ₄		-140.0	-125.0	-118.5	-111.2	-102.3	-96.6	-92.2	-87.0	-81.5	-76.0	-149.9
Stannic chloride	SnCl ₄		-51.3	-31.0	-20.4	-9.3	+3.5	11.7	22.0	39.8	58.5	78.0	
hydride	SnH ₄		-12.0	+10.7	21.8	34.0	48.5	57.0	69.0	87.3	108.0	131.7	
Tin tetramethyl	Sn(CH ₃) ₄		-13.9	+9.4	21.3	34.2	48.5	57.0	69.0	87.3	108.0	131.7	
trimethyl-ethyl	Sn(CH ₃) ₃ C ₂ H ₅		3990	4337	4507	4690	4886	5007	5168	5405	5666	5929	-30
trimethyl-propyl	Sn(CH ₃) ₃ C ₃ H ₇		-71.4	-56.5	-49.2	-41.5	-33.0	-27.5	-20.3	-10.0	+1.2	17.3	-0.5
Tungsten hexafluoride	WF ₆		-58.0	-22.0	-13.0	-5.2	+4.4	10.4	18.2	30.0	42.7	55.7	69.2
Vanadyl trichloride	VOCl ₃		-23.2	+0.2	12.2	26.6	40.0	49.8	62.3	82.0	103.5	127.2	
Xenon	Xe		-168.5	-138.2	-152.8	-147.1	-141.2	-137.7	-132.0	-125.4	-117.1	-108.0	-111.4
Zinc	Zn		427	550	593	632	673	700	736	788	844	907	419.4
chloride	ZnCl ₂		428	481	508	536	566	584	610	648	689	732	365
fluoride	ZnF ₂		970	1053	1086	1129	1175	1207	1254	1329	1417	1497	872
diethyl	Zn(C ₂ H ₅) ₂		-22.4	0.0	+11.7	24.2	38.0	47.2	59.1	77.0	97.5	118.0	-28
Zirconium bromide	ZrBr ₄		207	237	250	266	281	299	301	318	337	357	450
chloride	ZrCl ₄		190	217	230	243	259	268	279	295	312	331	437
iodide	ZrI ₄		264	297	311	329	344	355	369	389	409	431	499

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EXHIBIT 4-3

METHOD FOR ESTIMATING STORAGE TANK EMISSIONS

4.3 STORAGE OF PETROLEUM PRODUCTS

*Revised by William M. Vataavuk
and Richard K. Burr*

Fundamentally, the petroleum industry consists of three operations (1) crude oil production, (2) petroleum refining, and (3) transportation and marketing of finished products. Associated with these operations are evaporative emissions of various organic compounds, either in pure form or as mixtures.

From an air pollution standpoint, the petroleum industry is defined in terms of two kinds of evaporative losses: (1) storage and (2) marketing and transportation. (See Figure 4.4-1 for schematic of the industry and its points of emission.)

4.3.1 Process Description¹⁻⁵

Petroleum storage evaporation losses are associated with the containment of liquid organics in large vessels at oil fields, refineries, and product distribution terminals.

Six basic tank designs, are used for petroleum storage vessels: (1) fixed-roof (cone roof), (2) floating roof (single deck pontoon and double deck), (3) covered floating roof, (4) internal floating cover, (5) variable vapor space, and (6) pressure (low and high).

The fixed roof tank (Figure 4.3-1) is the least expensive vessel for storing certain hydrocarbons and other organics. This tank generally consists of a steel, cylindrical container with a conical roof and is equipped with a pressure/vacuum vent, designed to operate at slight deviations (0.021 kg/m^2 maximum) from atmospheric pressure.

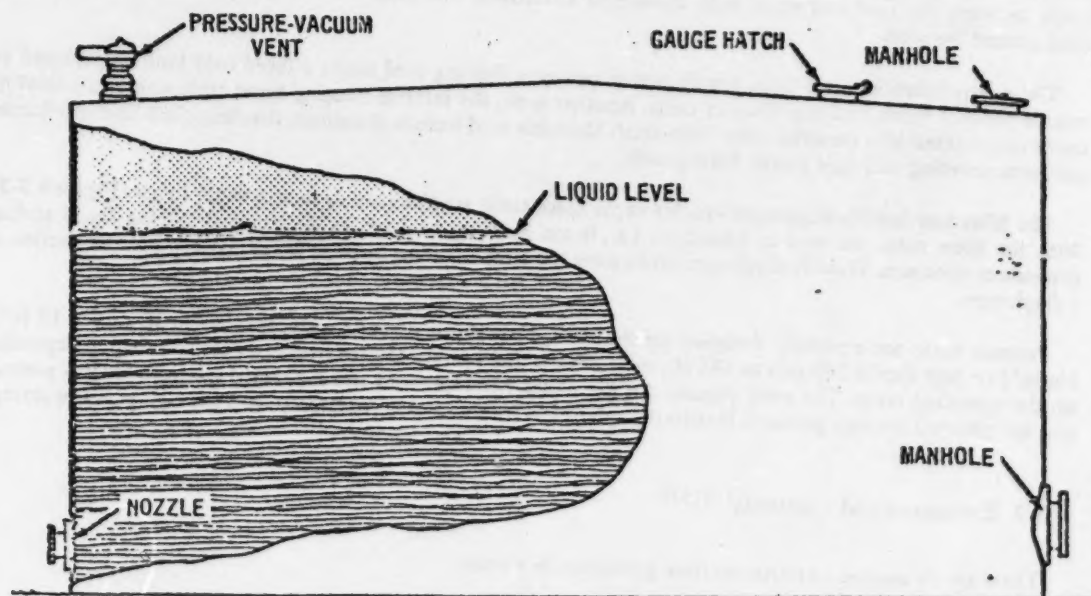


Figure 4.3-1. Fixed roof storage tank.

A floating roof tank is a welded or riveted circular vessel with an external float-type pan or pontoon roof (single- or double-deck) equipped with single or double mechanical seals (Figure 4.3-2).

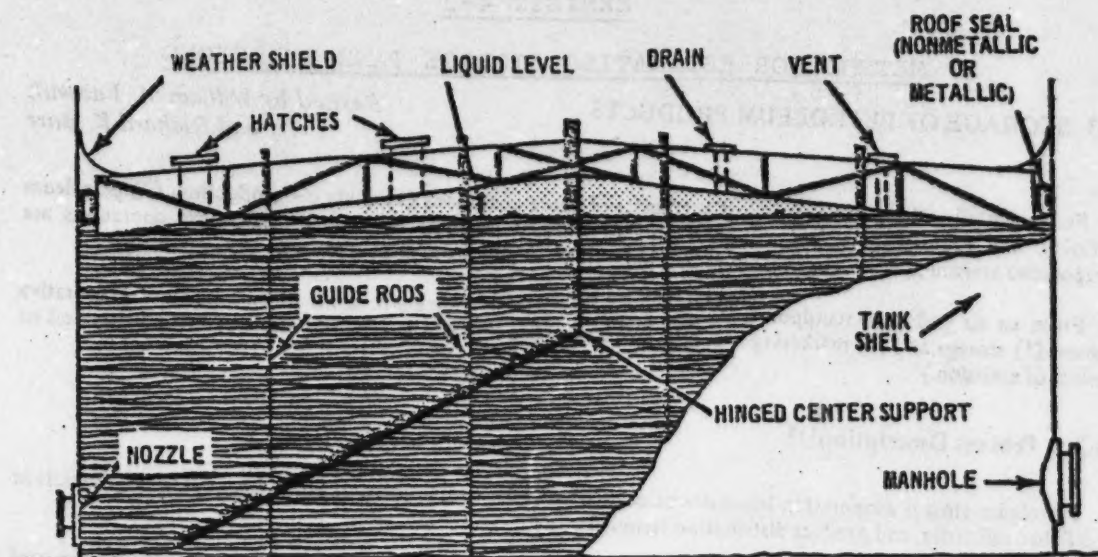


Figure 4.3-2. Double-deck floating roof storage tank (nonmetallic seal).

The floating roof prevents the formation of a volume of organic vapor above the liquid surface, which would otherwise be vented or displaced during filling and emptying. The seal, which is designed to close the annular space between the roof and vessel wall, consists of a relatively thin-gauge shoe ring supported against the tank shell around the roof.

The covered floating roof tank, simply a steel pan-type floating roof inside a fixed roof tank, is designed to reduce product losses and maintenance costs. Another type, the internal floating cover tank, contains a floating cover constructed of a material other than steel. Materials used include aluminum sheeting, glass-fiber-reinforced polyester sheeting, and rigid plastic foam panels.

The lifter and flexible diaphragm variable vapor space tanks are also used to reduce vapor losses (Figure 4.3-3). With the lifter tank, the roof is telescopic; i.e., it can move up or down as the vapor above the liquid surface expands or contracts. Flexible diaphragm tanks serve the same function through the expansion and contraction of a diaphragm.

Pressure tanks are especially designed for the storage of volatile organics under low (17 to 30 psia or 12 to 21 Mg/m^2) or high (up to 265 psia or 186 Mg/m^2) pressure and are constructed in many sizes and shapes, depending on the operating range. The most popular are the noded hemi-spheroid and the noded spheroid for low pressure and the spheroid for high pressure. Horizontal cylindrical forms are also commonly used for high pressure storage.

4.3.2 Emissions and Controls^{1-3,5-7}

There are six sources of emissions from petroleum in storage.

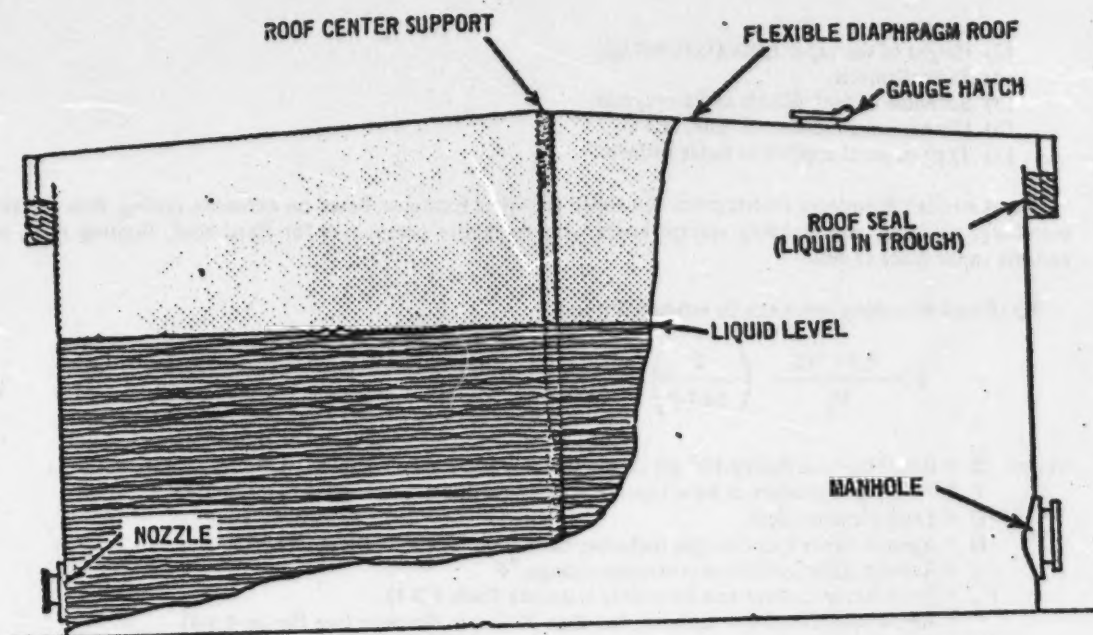


Figure 4.3-3. Variable vapor storage tank (wet-seal lifter type).

Breathing losses are associated with fixed roof tanks and consist of vapor expelled from the tank because of thermal expansion, barometric pressure changes, and added vaporization of the liquid.

Working losses consist of hydrocarbon vapor expelled from the vessel as a result of emptying or filling operations. Filling losses represent the amount of vapor (approximately equal to the volume of liquid input) that is vented to the atmosphere through displacement. After liquid is removed, emptying losses occur, because air drawn in during the operation results in growth of the vapor space. Both filling and emptying (together called "working") losses are associated primarily with fixed roof and variable vapor space tanks. Filling losses are also experienced from low pressure tankage, although to a lesser degree than from fixed roof tanks.

Primarily associated with floating roof tanks, standing storage losses result from the improper fit of the seal and shoe to the tank shell.

Wetting losses with floating roof vessels occur when a wetted tank wall is exposed to the atmosphere. These losses are negligible.

Finally, boiling loss is the vapor expelled when the temperature of the liquid in the tank reaches its boiling point and begins to vaporize.

The quantity of evaporation loss from storage tanks depends on several variables:

- (1) True vapor pressure of the liquid stored,
- (2) Diurnal temperature changes in the tank vapor space,

- (3) Height of the vapor space (tank outage).
- (4) Tank diameter.
- (5) Schedule of tank fillings and emptyings.
- (6) Mechanical condition of tank, and
- (7) Type of paint applied to outer surface.

The American Petroleum Institute has developed empirical formulae, based on extensive testing, that correlate breathing, working, and standing storage losses with the above parameters for fixed roof, floating roof, and variable vapor space vessels.

Fixed roof breathing losses can be estimated from:

$$B = \frac{2.74 WK}{V_c} \left(\frac{P}{14.7-P} \right)^{0.68} D^{1.73} H^{0.51} \Delta T^{0.50} F_p C \quad (1)$$

- where: B = Breathing loss, lb/day-10³ gal capacity
P = True vapor pressure at bulk liquid temperature, psia
D = Tank diameter, feet
H = Average vapor space height, including correction for roof volume, feet
ΔT = Average daily ambient temperature change, °F
F_p = Paint factor, determined from field tests (see Table 4.3-1)
C = Adjustment factor for tanks smaller than 20 feet in diameter (see Figure 4.3-4)
V_c = Capacity of tank, barrels
K = Factor dependent on liquid stored:
= 0.014 for crude oil
= 0.024 for gasoline
= 0.023 for naphtha jet fuel (JP-4)
= 0.020 for kerosene
= 0.019 for distillate oil
W = Density of liquid at storage conditions, lb/gal

Table 4.3-1. PAINT FACTORS FOR FIXED ROOF TANKS^a

Tank Color		Paint factor (F _p)	
		Paint condition	
Roof	Shell	Good	Poor
White	White	1.00	1.15
Aluminum (specular)	White	1.04	1.18
White	Aluminum (specular)	1.16	1.24
Aluminum (specular)	Aluminum (specular)	1.20	1.29
White	Aluminum (diffuse)	1.30	1.38
Aluminum (diffuse)	Aluminum (diffuse)	1.39	1.46
White	Gray	1.30	1.38
Light gray	Light gray	1.33	1.44 ^b
Medium gray	Medium gray	1.46	1.58 ^b

^aReference 2.

^bEstimated from the ratios of the seven preceeding paint factors.

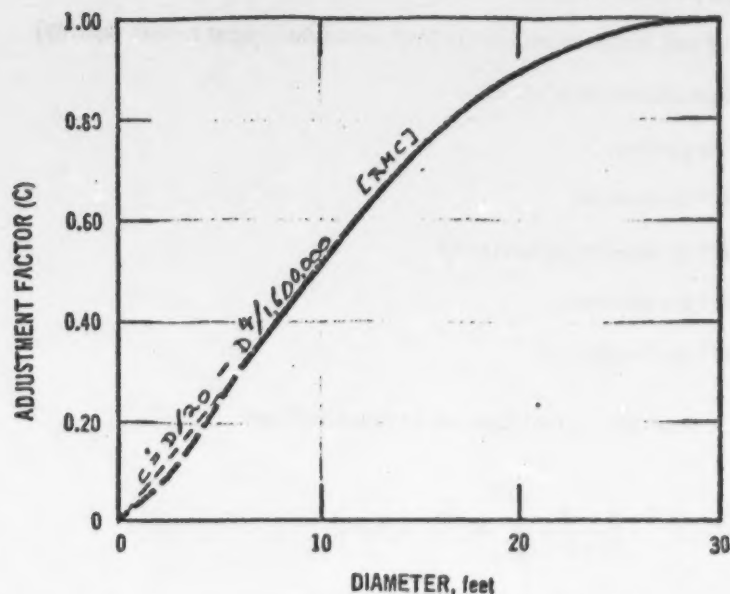


Figure 4.3-4. Adjustment factor for small-diameter fixed roof tanks.²

Breathing losses of petrochemicals from fixed roof tanks can be estimated from the respective gasoline loss factor, calculated at their storage temperature:

$$B_p = 0.08 \left(\frac{M_p}{W_G} \right) \left(\frac{P_p}{P_G} \right) B_G \quad (2)$$

where: B_p, B_G = Breathing losses of petrochemical (p) and gasoline (G), lb/day- 10^3 gal

M_p = Molecular weight of petrochemical (p), lb/mole

W = Liquid density of gasoline, lb/gal

P_p, P_G = True vapor pressures of petrochemical (p) and gasoline (G) at their bulk storage temperature, psia

This same correlation can also be used to estimate petrochemical working loss, standing storage loss, or any other kind of loss from any storage tank.

A correlation for fixed roof tank working loss (combined emptying and filling) has also been developed:

$$F_f = 1000 W_m P \left(\frac{180 + N}{6N} \right) \quad (3)$$

where: F_f = Working loss, lb/ 10^3 gal throughput

P = True vapor pressure at bulk liquid temperature, psia

N = Number of tank turnovers per year (ratio of annual throughput to tank capacity)

m = Factor dependent on liquid stored:

= 3×10^{-4} for gasoline

= 2.25×10^{-4} for crude oil

= 3.24×10^{-4} for naphtha jet fuel (JP-4)

= 2.95×10^{-4} for kerosene

= 2.76×10^{-4} for distillate oil

Standing storage losses from floating roof tanks can be calculated from:

$$S = \frac{2.74 WK_t}{V_c} D^{1.5} \left(\frac{P}{14.7 - P} \right)^{0.7} V_w^{0.7} K_s K_c K_p \quad (4)$$

where: S = Standing storage evaporation loss, lb/day- 10^3 gal capacity

K_t = Factor dependent on tank construction:

= 0.045 for welded tank, pan/pontoon roof, single/double seal

= 0.11 for riveted tank, pontoon roof, double seal

= 0.13 for riveted tank, pontoon roof, single seal

= 0.13 for riveted tank, pan roof, double seal

= 0.14 for riveted tank, pan roof, single seal

D = Tank diameter, feet; for $D \geq 150$ feet (45.8 m) use " $D\sqrt{150}$ " instead of " $D^{1.5}$ "

V_w = Average wind velocity, mi/hr

K_s = Seal factor:

= 1.00 for tight-fitting, modern seals

= 1.33 for loose-fitting, older seals (typical of pre-1942 installation)

K_c = Factor dependent on liquid stored:

= 1.00 for gasoline

= 0.75 for crude oil

= 0.96 for naphtha jet fuel (JP-4)

= 0.83 for kerosene

= 0.79 for distillate oil

K_p = Paint factor for color of shell and roof:

= 1.00 for light gray or aluminum

= 0.90 for white

Finally, filling losses from variable vapor space systems can be estimated by:

$$F_v = \frac{1000 WmP}{V_t} (V_t - 0.25V_eN) \quad (5)$$

where: m = Factor dependent on liquid stored (same as equation 3)

F_v = Filling loss, lb/10³ gal throughput

V_t = Volume of liquid throughput, bbl/year

V_e = Volume of expansion capacity, barrels

N = Number of turnovers per year

W = Density of liquid at storage conditions, lb/gal

Equations 1 through 5 can be used to calculate evaporative losses, provided the respective parameters are known. For those cases where such quantities are unknown or for quick loss estimates, however, Table 4.3-2 provides typical emission factors. Refinement of emission estimates by using these loss correlations may be desirable in areas where these sources contribute a substantial portion of the total evaporative emissions or are of major consequence in affecting the air quality.

The control methods most commonly used with fixed roof tanks are vapor recovery systems, which collect emissions from storage vessels and send them to gas recovery plants. The four recovery methods used are liquid absorption, vapor compression, vapor condensation, and adsorption in activated charcoal or silica gel.

Overall control efficiencies of vapor recovery systems vary from 90 to 95 percent, depending on the method used, the design of the unit, the organic compounds recovered, and the mechanical condition of the system.

In addition, water sprays, mechanical cooling, underground liquid storage, and optimum scheduling of tank turnovers are among the techniques used to minimize evaporative losses by reducing tank heat input.

Table 4.3-2. EVAPORATIVE EMISSION
EMISSION FACTOR

Product	Vapor pressure ratio (P/P _G)	Mola wt (M) (lb/mole)	Floating roof			
			Standing storage loss			
			"New tank" conditions		"Old tank" conditions	
			lb/day- 10 ³ gal	kg/day- 10 ³ liter	lb/day- 10 ³ gal	kg/day- 10 ³ liter
Crude oil ^c		64.5	0.029	0.0034	0.071	0.0086
Gasoline ^c		56.8	0.033	0.0040	0.088	0.011
Naphtha jet fuel (JP-4) ^c		63.3	0.012	0.0014	0.029	0.0034
Kerosene ^c		72.7	0.0052	0.00063	0.012	0.0015
Distillate fuel ^c		72.7	0.0052	0.00063	0.012	0.0015
Acetone	0.543	58.1	0.014	0.0017	0.036	0.0043
Ammonium hydroxide (28.8 % solution)	1.53	35.1	0.023	0.0028	0.062	0.0074
Benzene ^c	0.2108	78.1	0.0074	0.00089	0.020	0.0023
Isobutyl alcohol	0.0263	74.1	0.00086	0.00010	0.0023	0.00028
Tertbutyl alcohol	0.0843	74.1	0.0029	0.00034	0.0074	0.00089
Carbon tetrachloride	0.264	153.8	0.018	0.0021	0.048	0.0057
Cyclohexane ^c	0.230	84.2	0.0083	0.0010	0.022	0.0027
Cyclopentane ^c	0.776	70.1	0.024	0.0028	0.062	0.0074
Ethyl acetate	0.210	88.1	0.0081	0.00097	0.021	0.0025
Ethyl alcohol	0.120	46.1	0.0024	0.00029	0.0064	0.00074
Freon II	2.01	137.4	0.12	0.014	0.32	0.038
n-Heptane ^c	0.103	100.2	0.0045	0.00054	0.012	0.0014
n-Hexane ^c	0.353	86.2	0.013	0.0016	0.036	0.0043
Hydrogen cyanide	1.42	27.0	0.017	0.0020	0.043	0.00051
Isooctane ^c	0.112	114.2	0.0055	0.00066	0.015	0.0018
Isopentane ^c	1.86	72.2	0.057	0.0069	0.15	0.018
Isopropyl alcohol	0.0933	60.1	0.0024	0.00029	0.0064	0.00077
Methyl alcohol	0.272	32.0	0.0038	0.00046	0.010	0.0012
n-Pentane ^c	1.26	72.2	0.038	0.0046	0.10	0.012
Toluene ^c	0.0594	92.1	0.0024	0.00029	0.0062	0.00074

^aReferences 2, 3, 6, and 7.

^bFactors based on following conditions:
Storage temperature: 63°F (17.2°C).
Daily ambient temperature change: 15°F (-9.5°C).
Wind velocity: 10 mi/hr (4.5 m/sec).

	Reid vapor pressure		True vapor pressure	
	psia	Mg/m ³	psia	Mg/m ³
Crude oil	7.0	4.9	4.6	3.2
Gasoline	10.5	7.4	5.8	4.1
Naphtha jet fuel (JP-4)	2.5	1.75	1.2	0.84
Kerosene	≤0.5	≤0.35	≤0.5	≤0.35
Distillate oil	≤0.5	≤0.35	≤0.5	≤0.35

^cIndicates petroleum products whose evaporative emissions are exclusively hydrocarbons (i.e., compounds containing only the elements hydrogen and carbon).

Typical fixed- and floating-roof tanks

Diameter: 90 ft (27.4 m) for crude, JP-4, kerosene, and distillate; 110 ft (33.6 m) for gasoline and all petrochemicals.

Height: 44 ft (13.4 m) for crude, JP-4, kerosene, and distillate; 48 ft (14.6 m) for gasoline and all petrochemicals.

Capacity: 50,000 bbl (7.95 × 10⁴ liter) for crude, JP-4, kerosene, and distillate; 67,000 bbl (10.65 × 10⁴ liter) for gasoline and all petrochemicals.

Outage: 50 percent of tank height.

Turnovers per year: 30 for crude oil; 13 for all others.

FACTORS FOR STORAGE TANKS^{a, b}
RATING: A

Fixed roof						Variable vapor space	
Breathing loss				Working loss		Working loss	
"New tank" conditions		"Old tank" conditions					
lb/day- 10 ³ gal	kg/day- 10 ³ liter	lb/day- 10 ³ gal	kg/day- 10 ³ liter	lb/10 ³ gal throughput	kg/10 ³ liter throughput	lb/10 ³ gal throughput	kg/10 ³ liter throughput
0.15	0.018	0.17	0.020	7.3	0.88	Not used	Not used
0.22	0.026	0.25	0.031	9.0	1.1	10.2	1.2
0.069	0.0033	0.079	0.0095	2.4	0.29	2.3	0.28
0.036	0.0043	0.041	0.0048	1.0	0.12	1.0	0.12
0.038	0.0043	0.041	0.0048	1.0	0.12	1.0	0.12
0.093	0.011	0.10	0.013	3.7	0.45	4.2	0.51
0.16	0.018	0.18	0.021	6.3	0.76	7.1	0.86
0.050	0.0057	0.057	0.0069	2.0	0.24	2.3	0.27
0.0057	0.00067	0.0064	0.0079	0.23	0.028	0.26	0.031
0.018	0.0021	0.021	0.0026	0.74	0.90	0.83	0.099
0.12	0.014	0.14	0.018	4.8	0.58	5.4	0.63
0.057	0.0067	0.064	0.0079	2.3	0.28	2.6	0.31
0.16	0.019	0.18	0.022	6.4	0.77	7.2	0.87
0.055	0.0062	0.062	0.0074	2.2	0.27	2.5	0.30
0.016	0.0019	0.018	0.0022	0.65	0.079	0.73	0.089
0.81	0.098	0.92	0.11	32.4	3.9	36.7	4.4
0.031	0.0035	0.033	0.0040	1.2	0.15	1.4	0.16
0.088	0.010	0.10	0.012	3.6	0.43	4.0	0.49
0.11	0.013	0.13	0.015	4.5	0.54	5.1	0.61
0.038	0.0043	0.043	0.0051	1.5	0.18	1.7	0.21
0.39	0.047	0.45	0.053	15.7	1.9	17.8	2.1
0.016	0.0019	0.019	0.0022	0.66	0.080	0.74	0.090
0.026	0.0031	0.029	0.0034	1.0	0.13	1.2	0.14
0.26	0.032	0.30	0.036	10.6	1.3	12.0	1.4
0.016	0.0019	0.018	0.022	0.64	0.077	0.73	0.087

Typical floating-roof tank

Paint factor (K_p): New tank-white paint, 0.90; Old tank-white/aluminum paint, 0.95.

Seal factor (K_s): New tank-modern seals, 1.00; Old tank-50 percent old seals, 1.14.

Tank factor (K_t): New tank-welded, 0.045; Old tank-50 percent riveted, 0.088.

Typical fixed-roof tank

Paint factor (F_p): New tank-white paint, 1.00; Old tank-white/aluminum paint, 1.14.

Typical variable vapor space tank

Diameter: 50 ft (15.3 m).

Height: 30 ft (9.2 m).

Capacity: 10,500 bbl (1.67×10^6 liter).

Turnovers per year: 6.

REFERENCES FOR SECTION 4.3

1. Control of Atmospheric Emissions from Petroleum Storage Tanks. Petroleum Committee, Air Pollution Control Association. J. Air Pol. Control Assoc. 21(5):260-268, May 1971.
2. Evaporation Loss from Fixed Roof Tanks. American Petroleum Institute, New York, N.Y. API Bulletin Number 2518. June 1962.
3. Evaporation Loss from Floating Roof Tanks. American Petroleum Institute, New York, N.Y. API Bulletin Number 2517. February 1962.
4. Evaporation Loss in the Petroleum Industry — Causes and Control. American Petroleum Institute, New York, N.Y. API Bulletin Number 2513. February 1959.
5. Personal communication with personnel in Engineering Services Branch, Emission Standards and Engineering Division, Office of Air Quality Planning and Standards, Environmental Protection Agency, Research Triangle Park, N.C. November 1972.
5. Petrochemical Evaporation Loss from Storage Tanks. American Petroleum Institute, New York, N.Y. API Bulletin Number 2523. November 1969.
7. Use of Variable Vapor Space Systems to Reduce Evaporation Loss. American Petroleum Institute, New York, N.Y. API Bulletin Number 2520. September 1964.

CHAPTER 5

CONTROL TECHNIQUES

This chapter will include a description of the air pollution control techniques most applicable to the reduction or elimination of toxic substance emissions. For more details on the subject of the techniques mentioned here, and for descriptions of some of the less-generally applicable emission reduction measures, the reader is referred to such documents as EPA Publication Numbers AP-68, "Control Techniques for Hydrocarbons and Organic Solvent Emissions from Stationary Sources" (11), AP-51, "Control Techniques for Particulate Air Pollutants" (12), and AP-40, "Air Pollution Engineering Manual" (13).

One of the simplest and most highly efficient emission control techniques available is containment. The keeping of toxic materials in closed tanks, vessels, containers and other processing units that do not leak, are not allowed to overflow, and are not vented to the atmosphere any more often and in any greater quantity than is absolutely necessary will go a long way toward reducing atmospheric emissions. In the case of volatile materials, such containment may require equipment construction features that will enable considerable vapor pressures to be withstood.

Process modifications often prove to be a relatively easy method of effecting emission reductions. As discussed previously, the lowering of temperatures and raising of pressures tend to reduce the equilibrium vapor-phase concentrations of pollutants, and the minimization of exposures to air currents tends to reduce evaporation and aerosol generation rates. Reducing the amounts of toxic materials used or formed in processes, or substitution with a less-toxic or non-toxic material, is another simple type of emission control measure. Operating and maintenance

practices that can help to reduce emissions include the prevention of leaks, overflows, and spills, and the inspection of pressure relief valves to insure their proper closure and seating, and of gaskets, packing, seals and emergency rupture discs to insure their integrity.

Concerning types of add-on air pollution control equipment, the most widely applicable to organic gaseous toxic substance emissions are adsorbers and afterburners. Both are versatile enough to control the emissions of a very wide range of organic materials, and can be highly efficient over wide ranges of pollutant concentrations if properly designed, operated, and maintained.

The adsorption of the toxic substance onto activated carbon or another suitable medium is generally most economical when very low pollutant concentrations are involved, or when the recovered material would be of significant value and when the pollutant is not too volatile to be effectively adsorbed (such as is often the case for materials normally occurring only in the gaseous state). When the adsorptive capacity of the activated carbon or other medium is attained, the medium must be either replaced or regenerated (e.g., by steaming followed by cooling), in which latter case the pollutant can ordinarily be either re-used or incinerated.

The use of either direct-flame or catalytic afterburners to convert gaseous organic pollutants to harmless carbon dioxide and water (accompanied in some cases by some less harmless combustion products) is most economical at higher concentrations of pollutants that are not worth recovering, and for pollutants too volatile to be effectively adsorbed. An afterburner should be designed to have a sufficient gas stream residence time, or volume-of-combustion-chamber to volumetric-flow-rate-at-combustion-temperature ratio (normally at least about 0.3 to 0.5 seconds), a sufficient combustion chamber temperature (normally 1200°F to 2000°F

for direct-flame units, but as little as about 500°F to 800°F for catalytic units), and a sufficient entrance throat velocity (in direct-fired units) to result in good turbulence for thorough mixing (normally 25 to 50 feet per second).

Condensers (both those involving indirect heat transfer, such as shell-and-tube types, and those involving direct cooling medium-gas stream contact, such as the barometric types that cool through the latent heat effect as sprayed water evaporates into the gas stream) and absorbers (for example, packed columns with circulating liquids) are often employed in chemical processing plants, but typical process units would seldom be efficient enough to serve as final gaseous emission control devices.

In the case of inorganic gaseous emissions, a wide variety of wet scrubbing techniques could be considered for the achievement of emission control. The solubility of the gas of concern in the scrubbing liquid (which would often require adjustment to either an acidic or an alkaline condition) would be of primary concern; solubilities can be checked in such references as the CRC "Handbook of Chemistry and Physics," and R.H. Perry and C.H. Chilton's "Chemical Engineers' Handbook." Other important scrubber parameters include the liquid-to-gas flow rate ratio (L/G), the gas stream pressure drop (ΔP), and the contact time and conditions.

Particulate toxic substance emissions are most efficiently controlled by fabric filters (e.g., as contained in baghouses) or by panel filters. In the former case, the dust is generally removed in place by shaking or reverse-air techniques, while in the latter case the panels must be removed at intervals for replacement or reconditioning. Filtration is highly reliable if the media are correctly installed and maintained. The most important operational parameter is the

gas stream pressure drop, which will decrease if the gas stream is by-passing the media because of incorrect installation, excessive dust build-up, defective seals, a loss of media integrity, or other problems. For a toxic particulate pollutant whose physical nature renders filtration unsuitable, wet scrubbing is most likely to be employed. Cyclones, impingement separators and settling chambers would only infrequently provide adequate collection efficiencies for the final control of toxic particulate emissions. Electrostatic precipitators are much more complex control devices that can be very efficient but also sensitive and unreliable for most of the types of applications discussed here.

The reduction of both gaseous and particulate emissions depends not only upon the effective operation of add-on air pollution control equipment, but also upon the efficiency with which fugitive contaminants are captured and ducted to the control devices. In this regard, the importance of adequate hood design should not be overlooked. Hoods should be designed and operated so as to provide air velocities at locations of contaminant releases of at least the values indicated in Exhibit 5-1 (14).

A word on the utilization of tall stacks, or other such elevated release points, is appropriate at this point, since these are frequently employed for the purpose of reducing ground-level air pollutant concentrations. Many are of the opinion that a tall stack constitutes a simple and effective air pollution control device, resulting in the greatly increased atmospheric dilution of emissions; it is true that many of the principal pollutants are formed in nature at rates approaching or exceeding anthropogenic emission rates, but are harmless because of their distribution over wide areas of the globe. The same cannot usually be said of toxic substance emissions, many of which do not even exist in nature, and would tend to reach intolerable levels if emitted indefinitely,

even at low rates, because of the lack of natural means for their elimination from the environment. Thus, higher toxic substance release points may simply result in the substances being distributed over wider areas and adversely affecting more sensitive individuals and receptors, before the effects are noted, the causal substance detected, and the source of the emissions identified. For these reasons, tall stacks are not generally believed to be the proper means of effecting toxic substance air pollution control.

EXHIBIT 5-1

AIR VELOCITIES REQUIRED AT LOCATIONS
OF CONTAMINANT RELEASES (14)

<u>Initial Dispersion of Contaminant</u>	<u>Examples of Contaminant Sources</u>	<u>Range of Required Capture Velocity (fpm)</u>
Released with practically no velocity into quiet air	Evaporation from tanks, degreasing, etc.	50-100
Released at low velocity into moderately still air	Spray booths, intermit- tent container filling, low-speed conveyor transfers, welding, plating, pickling	100-200
Active generation into zone of very rapid air motion	Spray painting in shal- low booths, barrel fil- ling, conveyor loading, crushers	200-500
Released at high initial velocity into zone of very rapid air motion	Grinding, abrasive blasting, tumbling	500-2000

Note: Greater capture velocities may be required because of the presence of externally-induced air motion such as room, thermal or mechanical currents.

CHAPTER 6

START-UPS, MALFUNCTIONS AND SHUT-DOWNS

This chapter deals with the excess emission situations that may be associated with process start-ups, malfunctions and shut-downs, in that these represent departures from normal operations during which ordinary emission control techniques may prove insufficient or ineffective.

Start-ups and shut-downs are relatively common occurrences that are often responsible for substantial portions of the total toxic substance emissions. One of the reasons for this fact is that many operations involving highly toxic materials are specialty processes conducted on a small scale, and in a batch rather than a continuous fashion, so that start-ups are frequent.

The cleaning and drying of reaction vessels, columns, piping and other appurtenances prior to start-ups or following shut-downs often necessitates the opening or exposure of this equipment to the air, during which evaporative emissions may occur. Such cleaning procedures may be especially common at specialty facilities where many different products are made in the same equipment.

When reaction vessels are charged with raw materials prior to start-up, and when these must be mixed, or when reaction vessels must be emptied following shut-down, and the products must be drummed, air that contains pollutants may be displaced more rapidly than at any time during the remainder of the operation, and spills and subsequent aerosol generation and/or evaporation may be the most likely to occur at these times. Often start-ups and shut-downs must be effected with some haste; often delays develop that prolong the time of exposure of toxic substances to the atmosphere; in either case, excess emissions may often be the result.

The multiplicity of tasks that need to be accomplished during start-ups and shut-downs, and the necessity that these be performed in a certain order, results in a higher likelihood of accidents and excessive emissions at these times. Air pollution control devices should be functioning before the processes whose emissions are to be controlled are started up, if possible, or else the devices should be on very soon after start-up is effected. Similarly, when shutting down, the pollution control devices should be turned off last, or as late as possible. In addition, the opening of any heated or pressured vessels containing toxic substances must be done with care if excess boil-over emissions are to be avoided.

Malfunctions that can result in excess toxic substance emissions may be either process-related or emission control device-related. When a process malfunction occurs that requires the shutting down of the operation, all of the types of excess emissions described above with respect to normal planned shut-downs may occur, but the abnormal and unplanned nature of the event results in an even greater likelihood of excess emissions. The emergency blow-down of an operation, during which materials may be removed from process equipment very rapidly in the interest of safety, can often be expected to result in exceeding the capacities of air pollution control devices to function effectively. If a process malfunction results in an excessive pressure build-up, an emergency relief valve may open or a rupture disc may burst, suddenly releasing a quantity of potentially toxic materials directly into the atmosphere.

Other, and often less dramatic, malfunctions involve only air pollution control equipment. This could involve such occurrences as the overheating and automatic by-passing of an adsorber or a baghouse (or, alternatively, the destruction of such equipment by heat or fire), or the loss of a wet scrubber's water supply. In such cases,

especially if there is no violation of applicable air pollution emission standards (as is often the case with toxic substance emissions) and if the resulting increased emissions are believed to be tolerable by the operator, the operation may simply be continued, perhaps indefinitely, without the benefit of air pollution emission controls.

CHAPTER 7

INSTRUMENTATION, MONITORING, RECORD-KEEPING AND REPORTING

The basic types of instrumentation related to toxic substance atmospheric emission evaluations provide the values of parameters associated with process conditions, air pollution control equipment operations, and gas stream properties. These instrumentation types are discussed in turn below.

Process instrumentation can enable determinations to be made of the concentrations and rates at which toxic pollutants may be evolved within process equipment. Conditions of temperature, pressure or vacuum, flow rate, weight or density, volume or level, and others in some cases are useful in uncontrolled emission estimation, being indicative (as discussed in greater detail previously) of such significant factors as toxic material vapor pressure and vapor-laden air displacement rates. Unusually high temperatures, vacuums, flow rates, levels, or rates of fluctuation of process conditions may be accompanied by abnormally high emissions.

Air pollution control equipment instrumentation is useful in estimating the removal efficiencies that may be obtained. In the case of an adsorption unit, the temperature of the bed is most important in determining the medium's capacity to adsorb a specified toxic substance, and unusual temperature increases may result in the bed actually becoming an emission source, as accumulations of potentially toxic materials may be desorbed. Such temperature increases may be attributable to the process emission source changing, a loss of cooling system effectiveness (where such a system is employed), or a latent heat of adsorption (which is related to the latent heat of condensation, or of evaporation, since the adsorption of a vapor is physically similar to its liquefaction from the gaseous state)

effect due to the adsorption of significant quantities of pollutants from the gas stream in a short period of time. The effectiveness of the adsorption medium's steam regeneration, where this step is employed, can be estimated by the temperature to which the bed is raised, and the temperature to which it is subsequently cooled before re-use, as well as by the amounts of condensed steam and organic materials accumulating during the regeneration stage. Finally, the gas stream pressure drop through the adsorption unit is related to the thickness of the bed, and the gas stream volumetric flow rate is related to the gas residence time in the bed, both of which are important parameters for estimating control efficiencies.

Afterburners may include combustion-zone temperature (which is about the same as exhaust temperature only if no heat recovery is employed) instrumentation, but the inlet gas stream volumetric flow rate, inlet temperature and pollutant heating value, and the rates of firing with natural gas (or other fuel, such as distillate oil if used) and of combustion air injection (if needed for the burner oxygen supply) can be used to calculate the combustion temperature by means of an enthalpy balance. The gas stream flow rate is also important because, if it is unusually low, the required degree of turbulence to effect complete pollutant combustion may not be achieved; while, if the flow rate is too high, in addition to the possibility of the combustion temperature dropping too low, the required residence time for complete combustion may not be obtained.

When scrubbers are utilized for emission control, the pollutant removal efficiencies obtained are ordinarily dependent upon the gas stream pressure drop and on the ratio of the liquid flow rate to the gas stream flow rate (L/G). In addition, the liquid stream pressure drop is of interest because an abnormally low reading may be indicative of insufficient atomization, and an unusually high

reading may be indicative of nozzle plugging (and reduced liquid flow). The acidity, alkalinity, density or other composition-indicator of the scrubbant may also be measured.

The functioning of a particulate matter filtration system is best indicated by the gas stream pressure drop, since an unusually low differential may result from gas stream by-passing (due to leaks, defective seals, incorrect valve settings, improper filter element installation or fit, tears in the filter cloth, etc.), and an unusually high pressure drop may indicate that emission control problems may be developing (such as the plugging of filter medium pores, or the malfunctioning of filter cleaning devices such as shakers or reverse-air equipment). Temperature recording instruments may indicate whether the filter material's upper temperature limit may be exceeded, or whether the dew point of the gas stream may be reached (which can result in filter material damage or simply difficulties due to an excessive pressure drop). The levels of collected particulate material in the hoppers of baghouses can also be checked to insure that the equipment is functioning.

Toxic substance atmospheric emission monitoring is not generally required by law and is often not practical because of the complexity and cost of the monitoring equipment that would be required. As a result, such monitoring would only infrequently be found at a continuous-type, large-scale operation and rarely found at a batch-type, small-scale operation. The results of in-plant monitoring undertaken to establish compliance with occupational safety and health standards, if available, may be useful in some cases but cannot be used directly since both the in-plant and ambient air concentrations, and the corresponding acceptable levels, will generally differ.

The recordkeeping and reporting of toxic substance atmospheric emissions is also not

required; however, the authority to enter and inspect emission source premises discussed previously includes provisions for access to relevant records. The inspection of process emission source and air pollution control equipment parameter values, as are often recorded either in log books or on strip-type or circular chart recording machines, can reveal not only typical values, but also departures from normal that may be related to excessive emissions as discussed in detail previously; however, the possibilities of faulty instrument readings and non-functioning sensors should be kept in mind. Thus, process emission source and air pollution control equipment operational records may serve as a useful inspection and evaluation aid if the reliability of the records is properly taken into account.

CHAPTER 8

FIELD INVESTIGATIONS

This chapter is devoted to describing the performance of field investigations of potential toxic substance atmospheric emission facilities; however, a thorough understanding of the previous chapters included in this manual is required for the successful performance of the inspection procedures outlined here, which are intended to insure that atmospheric pollution attributable to the release of toxic substances is not allowed to occur.

Field investigations may be conducted either as a matter of routine or for various other purposes, such as in response to complaints, in checking on a visible or odorous emission noticed by chance, or in following up corrective measures required to alleviate a known problem. Routine facility visits may be made at a frequency to be determined based on regulatory agency policy, for example, on a quarterly schedule; however, the visits should not be made at regular intervals or on a pre-arranged basis if the most accurate picture of routine operating and maintenance conditions is to be gained by the inspector. On the other hand, the cooperative arrangement of an inspection visit can be beneficial in insuring that production is scheduled to be on-going and that time will not be wasted in gaining entry to the plant and in presenting an itinerary of the visit. Thus, the above factors must be weighed in deciding whether or not the inspection should be arranged with the facility owner or operator in advance.

Certain items of safety and inspection equipment should be taken on the visit by the field investigator (see Exhibit 8-1). The safety equipment includes a hard hat, safety eyeglasses or goggles, chemical-resistant safety shoes or boots, and a gas mask equipped with activated carbon canisters (or other suitable safety respirator).

In some cases, such additional safety items as ear protectors (for example, cotton plugs), protective gloves, and fireproof clothing may be required. The investigator may find it advisable to check on the existence of any unusual safety requirements in advance, since source facility owners and operators may refuse the investigator entry if the required safety equipment is not available.

Items of inspection equipment that the investigator may have need of include the appropriate credentials, an inspection manual and forms, a notebook and writing implements, a wristwatch, a camera with film, a tape measure, a flashlight, a compass (if directions in the plant area are not well known to the inspector), and sample bags (with ties) or containers, with a pocket knife or scraper and a sample brush. The inspector may know some of these items not to be required, depending on the characteristics of the facility to be visited.

Prior to attempting to conduct an emission source facility inspection, the field investigator should seek whatever relevant information may be available in the files of environmental regulatory agencies, and in some cases other governmental agencies. This information may prove valuable in helping the inspector to prepare an itinerary for the visit, to fill in some of the information required on the inspection forms in advance (so that the data may simply be checked rather than written out while at the plant, leaving more of the inspection time for actual observation), and to more readily detect variations from normal operating conditions. Before leaving to visit the facility in question, the investigator should, of course, be certain that he can locate it readily.

When the field investigator reaches the vicinity of the plant, he should circumnavigate it and complete a copy of the pre-entry chemical

emission source inspection form presented here as Exhibit 8-2. Many of the general items of information to be filled out on the pre-entry inspection form are of obvious relevance. These include the facility name, the facility address, the person to contact, his telephone number, the inspector's name, the inspection date and time, and the reason for the inspection. Meteorological conditions such as temperature, wind speed, wind direction, cloud cover and precipitation are relevant both as factors having some bearing on process conditions, atmospheric emissions, ambient concentrations, and the inspector's evaluations. It should be noted that the atmospheric stability condition, which may greatly influence the relationship between emission rates and ground-level concentrations, can be approximated based on the time of day, wind speed and cloud cover (see Turner's "Workbook of Atmospheric Dispersion Estimates," EPA Publication Number AP-26, for more details (15)).

While it is desirable for the inspector to view the facility from all directions, any visible emission evaluations should be accomplished with the wind direction being roughly perpendicular to an imaginary line drawn between the observation point and the source, with the sun being roughly at the observer's back (or, if the observation is being made at night, with the moon or other light source behind the plume as seen by the observer), and with a suitable background against which the plume can be viewed. Since toxic substance emissions may be of concern even in very low concentrations and quantities, even the faintest of visible emissions should be recorded as such. The information to be recorded includes the plume release location, its opacity and color, a description of the background against which the plume opacity is judged, the observer's location, the distance and direction from the observer to the plume, and the photograph number (if any is taken). Visible emission evaluations should be made in accordance with Method 9 of 40 CFR 60, Appendix A.

The odorous emission section of the pre-entry inspection form must of necessity be completed with largely subjective information. Odor strength, type and persistence should be judged carefully and recorded. The observer's location, the apparent release location, the distance and direction to the apparent source, and the number of any photograph taken should also be recorded. Any odorous emission evaluations must of course be made in the direction from the source toward which the wind is blowing at the time. As a guide for the estimation of toxic substance ambient concentrations, a list of odor descriptions and thresholds was presented as Exhibit 3-6. It may at times be advisable for a field investigator to familiarize himself with the odors characteristic of toxic substances that may be released from a plant that he is about to visit or has just visited.

The pre-entry inspection form also includes provisions for recording data regarding particulate deposition and ecological effects on any type of receptor. Observations of cumulative particulate matter deposition or ecological effects (which will probably only very seldom be evident, even to a trained observer familiar with the area's ecology) will most often be made in the direction of the prevailing wind at the time of the inspection visit, but may also be more frequent where the potentially sensitive ecological element is particularly close to the source. In the case of particulate matter deposition or a suspected ecological effect, photographs should be taken and samples should be obtained for subsequent analysis.

The field investigator may also wish to sketch the emission source facility location, for the purpose of showing relative source, receptor, and observation locations, before entering the plant. Such a sketch may help to clarify some of the information recorded above on the pre-entry inspection form.

When he has completed his pre-entry observations, the field investigator should proceed to the plant admission gate. As may be necessary to gain entry and to perform his duties, the inspector should present his credentials and state his intent; acquaint any plant official questioning the inspector's right to enter, examine records and copy information with the relevant provisions of Section 114 of the Clean Air Act (as discussed previously); and inform any plant official refusing to allow entry or inspection of the penalties prescribed under Section 113 of the Clean Air Act (as also discussed previously). Should the field investigator's right be persistently refused, he should make a written record of the name and position of the plant official involved and of any other relevant factors, depart from the plant, and report the incident to the environmental regulatory agency's attorney for further action.

If permitted to enter the premises of the facility, the field investigator should meet with the official in charge (who will often be the plant manager) or his designated representative (who may be the plant environmental engineer). The inspector should explain the purpose of his visit and propose an itinerary of what he would like to see and about how long he expects his visit to take. Ordinarily the inspector will want to review the plant's operating and maintenance records, logs and recording charts, making notes of any important emission-related information; inquire about the day's operating schedule and any unusual conditions, start-ups, malfunctions or shut-downs that may be occurring; and proceed with his observations of the on-going operations, the state of maintenance of process and control equipment, visible and odorous releases, and instrumentation readings related to atmospheric emissions.

A sample reactor inspection form is presented as Exhibit 8-3. The first few items to be entered on the form (facility name and address, inspector, date, and name of system), as well as on additional

forms to be described below, should not be omitted as they are necessary for the unambiguous identification of the inspection record, which may at some later time become inadvertently separated from other papers on which the identifying information has been recorded. The next information to be entered on the inspection form serves to identify the subject item of equipment, in this case the specific reactor, that may be a source of toxic air contaminant emissions to the atmosphere. The roll film numbers of any photographs taken of the reactor, whether from on or off the plant property, should also be recorded (as well as any pertinent notes regarding the on-going operation, the details of greatest interest, the view of the reactor being shown, etc.) on the inspection form; such photographs would generally not be intended for use as part of any subsequent litigation, but would rather serve to improve the field inspector's recollection of his visit as he writes his inspection report, to reveal details that he may have overlooked, and to confirm the identity of the subject reactor, should doubts arise for any reason, subsequent to the completion of the visit.

The remainder of the information to be entered on the reactor inspection form is that which would be required in order to arrive at an accurate judgment as to whether the reactor may constitute a significant source of potentially toxic atmospheric emissions. All other factors being equal, the magnitude of such emissions will often be approximately proportional to, or at least directly related to, the capacity of the reactor. Of the size-related items (capacity, diameter, and height or length), it would often be unnecessary to obtain the values of all three parameters; any two could be used to estimate the third (for a cylindrical vessel, $V = \pi d^2 h / 4$ or $V = \pi d^2 l / 4$, where V is the volume in cubic feet, d is the diameter in feet, h is the height in feet, and l is the length in feet), and the capacity alone would usually be sufficient for the field inspector's needs. While viewing

the reactor for the purpose of size estimation, the inspector should also note the equipment's apparent physical condition, for example, the presence of leaks. Evidence of the leaking or spillage of potentially toxic liquid or solid materials (which may later become airborne) may be seen either on the reactor vessel itself, on the ground or floor below, or elsewhere in the area. Indications of gaseous leaks may be visible either directly, or through resulting particulate deposition or corrosion patterns on equipment surfaces, or may be noticeable due to the odorous nature of the leaking gas.

The type of reactor operation, usually either batch or continuous, should be check-marked on the inspection form. Batch operations often entail greater atmospheric emissions per unit of product, since they involve frequent start-ups and shut-downs, with the charging and removal of materials and related displacements of particulate- and/or vapor-laden air or other gas; continuous operations, while often larger in terms of total production, are generally steadier in nature and more fully enclosed, with little net volume change or displacement occurring. The reactor charging method should also be checked; dumping or pouring materials into an open reactor porthole is far more likely to result in atmospheric emissions than is charging through a tightly connected pipe. Certain additional items to be check-marked on the reactor inspection form apply to the use of agitation, which may raise dust, liquid droplets, or vapors that are subsequently released; heating, which may promote active boiling (similar to mechanical agitation in effect) as well as increase the vapor pressures and gas-phase concentrations of potentially toxic materials; cooling, which usually has the reverse effect and thus may decrease emissions; pressurization, which may decrease the vaporization of potentially toxic materials but may also increase losses through leakage; vacuum operation, whose effects may be the reverse of those due to pres-

surization; and certain types of auxiliary equipment (for example, fractionation columns, reflux condensers, steam or water ejectors, wet scrubbers, combustible-gas burners, etc.), which may serve to reduce emissions, whether primarily intended as either process or air pollution control equipment.

Further information to be recorded on the reactor inspection form provides additional details that may be needed by the field inspector for the determination of the significance of toxic substance emissions. The processing time, in combination with the reactor capacity noted previously, can be used for the estimation of process weight rate, to which the emission rate is ordinarily related. Alternatively, plant log books may be consulted for production rate data. The temperature cycle data (for example, 30 minutes heating, 60 minutes at 250°F, 30 minutes cooling) are useful in determining that portion of the operation time during which the critical reactor conditions and maximum emissions may actually occur, and may often be recorded automatically on circular charts; the pressure cycle data may serve a similar purpose. Abnormal values of recorded temperatures and/or pressures may be indicative of emission-related malfunctions. The discharging method and cleaning method employed during the operation and maintenance of the reactor, as they relate to its toxic substance emission potential, should also be entered on the inspection form.

One of the most important sections of the reactor inspection form is that in which the raw materials, intermediates, products and by-products are listed. Only the amounts of the raw materials and products need ordinarily be listed, and the amounts for either group alone may often be sufficient to determine the amounts for the other group. The emissions of a particular toxic material would most often be expected to be proportional to the amount of that material present. While reaction

intermediates and by-products are usually only present in small quantities, often not measured, and may be estimated if necessary based on considerations of chemical equilibria, kinetics, and stoichiometry, these materials can sometimes be of concern in terms of emission toxicity, particularly where the raw materials and products are not toxic and emission controls are thus inefficient or non-existent. In any case, a knowledge of the materials present in the reactor is a prerequisite to a determination of the equipment's potential for significant toxic substance emissions. The relevant biological, chemical and physical properties of the materials present can be investigated in detail subsequent to the inspection visit in order to permit as accurately as possible an assessment of each material's toxicity and emission rate.

The reactor inspection form, as well as additional forms described below, also includes provisions for the recording of exhaust gas information. As the field inspector makes a note of the location and height above grade of the exhaust release point, he should also record the plume opacity, the existence of any odor downwind, and the numbers of any photographs he may have the opportunity to obtain. Of the volumetric gas flow rate, vent top-inside diameter, and gas exit velocity, if any two are obtained, the third may be directly calculated (from $G = \pi d^2 v / 4$, where G is the volumetric gas flow rate in cubic feet per second, d is the vent top-inside diameter in feet, and v is the gas exit velocity in feet per second). Of the three parameters, the volumetric gas flow rate is by far the most important (as it represents flow conditions elsewhere in the system, as well as at the exit), and it alone may often be sufficient for the inspector's needs; however, if in addition to the estimation of emission rate (for example, by multiplying the volumetric gas flow rate times the exhaust-gas concentration of a toxic material) the resulting ambient air concentration or deposition rate is to be estimated through the utilization of diffusion modeling techniques, either

the vent diameter or the exit velocity, or both, may first be required in order to estimate the rise of the plume above the top of the stack or vent. The gas exit temperature would be needed by the field investigator in any case, for the conversion of the volumetric gas flow rate to that which would occur elsewhere in the system, where the temperature may differ. Exhaust gas monitoring equipment readings (for example, for the concentration of total hydrocarbons), if available, should also be noted by the inspector.

A few additional items that pertain to potential exhaust gas release from reactors in particular may also be entered on the inspection form. These include the valve pressure setting (which should prevent unnecessary releases), the rupture disc pressure rating (which should be adequate to prevent unnecessary blowouts), their conditions, and the use of any blowdown and spill controls (for example, diked areas, knockout drums or tanks for containment, flares or scrubbers for emission reduction, etc.). Finally, the reactor inspection form includes space for a sketch of the system. This should be included for all but the simplest operations. Flow rates and conditions of temperature and pressure that vary locally within the system may be indicated on the sketch. The reverse side of the inspection form should be used where more space is required, whether for the sketch or for other information for which the front side of the form contains insufficient space.

A sample dryer inspection form is presented as Exhibit 8-4. Since many of the items of information required for the completion of this form were discussed above in connection with the reactor inspection form, only the items unique to the dryer inspection form will be discussed here. The type of dryer (agitated, fluid bed, gravity, pneumatic conveying, rotary, screen, screw conveyor, spray, or tray) and type of heat trans-

fer (direct or indirect) should interest the inspector since the degree to which the material being dried is exposed to and mixed with the drying medium (air or other gas) is an important factor in determining not only how much drying occurs but also how much of any toxic material present may be transferred to the gas stream. The chemical composition of the drying gas stream, if other than that of air, may be important for the determination of the emission control efficiency obtainable when using certain devices or techniques. The composition of the material to be dried is of obvious relevance, since the toxic substance of concern would normally be contained in this material, and its physical form (for example, powdered, granular, pelletized, etc.), as well as mesh size, would be necessary in order to evaluate the possibility or degree of particle entrainment expected. Since interparticle cohesion is also of importance in this respect, the percentages of moisture (or organic liquid) in the material both before and after drying are also of interest.

A form intended for use during the inspection of grinding and milling operations is presented as Exhibit 8-5. Again, since many of the items required to complete the grinding or milling operation inspection form were discussed previously in connection with the reactor inspection form, their descriptions will not be repeated here. The type of the mill (for example, ball, hammer, jet, pebble, planetary, ring-roller, rod, roller, tube, vibratory, etc.) is directly related to the intensity of the grinding operation, the degree of size reduction achieved, and, thus, the likelihood, magnitude and nature of atmospheric emissions from the equipment. It should be noted that only dry grinding or milling operations would normally be expected to result in particulate emissions. In this regard, information concerning the chemical composition of the material being processed should be supplemented by the physical form and mesh size of the material both before and after the

grinding or milling operation.

A storage tank inspection form is included as Exhibit 8-6. This particular form is designed so that a single copy may be employed during the inspection of a considerable number of material storage tanks, such as may be encountered on a tank farm or elsewhere on the grounds of a large chemical production facility. The reasons for the inclusion of specific identifying information on the form were discussed previously in connection with the reactor inspection form. Many of the additional items to be completed (for example, material stored, storage temperature, rated capacity, annual throughput, tank diameter, tank height, roof color, shell color, condition of paint and general state of repair, etc.) are employed directly in the estimation of evaporative emissions according to such methods as those detailed in "Compilation of Air Pollutant Emission Factors," EPA Publication Number AP-42, Section 4.3, which was presented earlier in this inspection manual.

Additional items required to complete the storage tank inspection form may be employed in modifying the results of such an emission calculation. For example, the tank vent pressure setting may be sufficient to prevent some or even all atmospheric releases from the equipment. Since the storage tank evaporative emission calculation procedure applies to equipment outdoors and in the open, reductions in or the elimination of exposure to direct solar radiational heating (as well as to the clear nighttime conditions that promote radiational cooling) and to the effects of the wind may indicate that a downward adjustment should be made to the calculated emission rate. The storage tank level indicator reading is more than just an evaporative emission calculation input parameter (and suitable assumptions, such as that the average condition is one in which the tank is half-filled, could be made without checking the indicator); rather, the level indicator should be in a functioning and readable condition

so as to serve as an aid in the prevention of overfilling and spillage.

Finally, the storage tank inspection form includes provision for the recording of the use of atmospheric emission control equipment. In the case of storage tanks, a variety of control techniques beyond the more generally applicable gaseous emission reduction methods (which, for example, include absorption in a wet scrubber, adsorption on activated carbon, condensation in an indirect heat exchanger, incineration in a direct flame afterburner, etc.) are often employed. Such methods may include storage tank design measures such as floating- or expansion-roof or pressurized construction; return lines to stationary tanks, tank trucks, railroad tank cars, etc. for the vapor-laden air displaced during filling operations; other types of vapor balance and recovery systems, some of which may be rather complex in nature (for descriptions of these see such references as "Air Pollution Engineering Manual," EPA Publication Number AP-40, Chapter 10); and spill containment measures such as the construction of dikes around tanks that can allow spilled materials to be removed by pumping or other collection measures before evaporation occurs.

A pump and compressor inspection form is presented as Exhibit 8-7. In general, the emissions of any potentially toxic material that is being handled may be expected to be dependent on the flow rate through the equipment. The inlet and outlet fluid temperatures and pressures are important in determining the amount of material that may escape at the locations of seals between moving and stationary parts (for example, at rotating impeller shafts and reciprocating piston connecting rods) and, less often, at other points. Mechanical seals (ordinarily flat face-plate pairs, one rotating and one stationary, perpendicular to rotating shafts) are generally superior (to packed seals) for liquid containment purposes, espe-

cially the internal type utilizing hydrostatic pressure for a tighter seal. When double mechanical seals are employed, a pressurized purge liquid may be introduced between them to prevent leakage of the toxic liquid being pumped. Labyrinth seals, used in handling gases, include multiple knife-edges or touch-points to achieve a cumulative pressure drop through the series of orifices that minimizes gas leakage; in addition, a pressurized non-toxic purge gas may be introduced into the seal to counter such leakage. Except where a lubricant or purging fluid is continuously introduced under pressure, a small amount of leakage is to be expected even from seals in good condition. Add-on emission control equipment for pump and compressor leakage is seldom employed. It should be noted that a single pump and compressor form can be completed for a number of similar items of equipment by filling in ranges of data or typical values, rather than data representative of a single item of equipment only.

A hood and ductwork inspection form is presented as Exhibit 8-8. These items are important for the reduction of fugitive toxic substance emissions. In general, the greater the volumetric ventilation rate utilized in a potential fugitive emission area, the greater the percentage of air pollutants that may be captured for conveyance to the air pollution control equipment. (If no such equipment is employed, the hooding and ventilation only serve to alleviate in-plant toxicity problems.) The hood type (the design should enclose the source area as much as possible, and include flanges around entrance edges to keep the air flow on the source side of the hood), the hood dimensions and, most important, the distance to the source (whose inverse square is usually roughly proportional to the induced air velocity) are all factors that affect the hood's fugitive emission capture efficiency (14). The existence of a high air velocity near a central duct opening in the hood, but very low velocities

near the edges of the hood, can be remedied by such air flow distribution aids as multiple take-off duct openings, baffles, filter banks, etc. The velocity at the source that must be induced by the hood for efficient air pollutant capture is dependent on both the source release velocity (ranging from high for grinding operations to negligible for slow evaporation) and on the presence of interfering air currents (due to open doors and windows, nearby equipment operations, etc.). Lengths of ductwork operating under conditions of positive pressure may permit the escape of toxic air pollutants, and connection locations that are not tight-fitting should be checked for air leakage.

An industrial waste incinerator inspection form is included as Exhibit 8-9. Such incinerators should not be overlooked by the inspector, since they may constitute highly significant sources of toxic air pollutant emissions. The number of internal combustion chambers (usually two or three) physically separated by refractory walls is directly related to the incineration efficiency that may be obtained, since abrupt changes in the direction of gas flow that occur between chambers improve the mixing of potential pollutants, combustion air, heat and flame. The volume of each chamber can be used to calculate the corresponding residence time (volume divided by volumetric gas flow rate at combustion temperature), which would normally total about 0.3 to as much as 10 seconds. The waste preparation and charging method is an important factor in determining the controllability of combustion conditions, which should be maintained free of such effects as erratic burning or sudden flame quenching. Similarly, the draft should be well controlled, with the combustion air being preheated for the most effective incineration. The operating temperature of the unit should be maintained as high as possible, the normal range being 1600 to 2000°F. Temperature controls are ordinarily also necessary for the protection of the equipment itself.

In order to provide for the recording of sufficient information regarding air pollution emission control equipment, whether used in conjunction with a reactor, dryer, grinder, mill, storage tank, incinerator, or other potential source of atmospheric contaminants, an emission control equipment inspection form has been included as Exhibit 8-10. The information that is to be entered on this form would be adequate to permit a reasonable estimation of control effectiveness to be made. Although a great number of additional items could be employed for the most accurate determination of control efficiency, the specific data required and the computational methods involved have been detailed by others (for example, see "Air Pollution Engineering Manual," EPA Publication Number AP-40, Chapters 4 and 5), and their description is beyond the scope of this manual.

In addition to the usual identification information, the emission control equipment inspection form includes provisions for the entry of the name of the process emission source whose emissions are being controlled by the subject equipment. Certain items should be recorded regardless of the type or types of control equipment being employed. These include the gas volumetric flow rate (specified as the inlet or outlet value), the entrance temperature of the gas emanating from the source equipment, the exit temperature of the gas from the final control device, and the gas stream pressure drop through the control system. Space is also provided on the emission control equipment inspection form for entering the operating condition (satisfactory, or unsatisfactory due to the leaking of gas, plugging of lines, overloading of hoppers, etc.) of each device.

The following sections of the emission control equipment inspection form pertain to specific categories of devices; each category utilized for the control of the subject process emission source should be check-marked. For the vapor condenser category, a knowledge of the type (for example,

shell-and-tube, barometric, etc.) of device is essential to the understanding of its operation. A barometric condenser also functions as a wet scrubber, effecting a removal of particulate matter and additional control of soluble vapors contained in the exhaust gas stream. Information regarding the cooling fluid, the coolant flow rate, the coolant inlet temperature and the coolant outlet temperature is useful for calculating the total amount of heat transferred, the reduction in the exhaust gas stream temperature, and thus, the quantity of vapor that is removed from the exhaust gas stream and converted to liquid form. For an indirect condenser (such as one of the shell-and-tube variety), the heat transfer area may be either used as a check (the total amount of heat transferred should equal the product of the heat transfer area, the average temperature difference between the coolant and exhaust gas streams, and the overall heat transfer coefficient, which may be approximated in accordance with the data and methods presented in "Chemical Engineers' Handbook" by Perry and Chilton), or may be used in place of accurate coolant flow rate and temperature data to estimate the amount of heat transferred, the decrease in exhaust gas temperature, and the condenser's effectiveness. If the exhaust gas temperature is monitored and recorded, such calculations may not be necessary.

Scrubbers may vary considerably in design and in effectiveness for the removal of either particulate matter, vapors, or both. The type of scrubber (for example, spray, packed, venturi or ejector) being used is a good though highly approximate indicator of the control efficiency that may be obtained. A knowledge of the scrubbing liquid composition and pH is important in the case of gaseous contaminant emission control, since the solubility or reactivity of the contaminant in the liquid may be critical to the scrubber's effectiveness. The scrubbant circulating flow rate is also relevant to the device's ability to remove contaminants from the exhaust gas stream

for many types of scrubbers, and equipment removal efficiency as a function of flow rate may be either calculated or located in pertinent reference books. Because of the great variations in scrubber designs often encountered, and the often strong dependence of effectiveness on the scrubber's physical shape and size, space has been provided for the entry of information regarding the device's geometrical form and key internal dimensions (affecting gas and liquid flow inside the equipment). Alternatively, the monitoring or analysis of scrub-bant composition may be combined with blowdown and make-up rates to result in an estimation of contaminant removal efficiency and atmospheric emission rate.

Afterburners for the incineration of vapors or fine particulate matter in the exhaust gas stream may be of the direct flame or catalytic type, either of which may involve heat recovery (where the hot gases leaving the device preheat the gases entering, through indirect heat exchange). Time, temperature and turbulence are critical to the effectiveness of the device, the residence time of the gases being dependent upon the inside volume of the device, the temperature attained being dependent upon the fuel firing rate and utilization of heat recovery, and the turbulence being a function of such factors as the linear gas velocity as it passes through the device. The monitoring of the maximum gas temperature would be a useful indicator of the emission control efficiency that may be obtained.

An adsorber may contain either activated carbon or another suitable material having a characteristic capacity (in pounds of adsorbate per pound of adsorbant in the bed) for the removal and retention of any gas stream contaminant. Regeneration, usually with steam, causes the contaminant that has been concentrated in the adsorbant while the bed was on-line to be released, and a final emission control step (condensation, incineration, and/or other methods) must then be employed. The tempera-

ture of the adsorption medium, which may be monitored and recorded throughout the control-regeneration-cooling/drying (usually with clean air) cycle, may be used to gain important insight regarding the functioning of the regenerating type of adsorption system.

Filter types include fabric filters or "bag-houses" from which the accumulated particulate material is removed by such methods as shaking or blowing with reverse-direction air jets; and panel filters, which are either cleaned or replaced periodically. Both the filter material (because of its resistance to corrosive or hot gases, which may destroy the fabric) and the total filter surface (because of the considerations of particulate loading and gas stream pressure drop, which may lead to excessive wear and by-passing) are important in determining the success of filtration as a control measure. The field investigator should carefully note the disposition of the collected dust, since the very high efficiency obtainable through appropriate filtration procedures may be seriously overestimated should portions of the collected dust be lost because of careless handling. Filter pressure-drop monitoring is very useful.

Cyclone types include simple, multiple (parallel) or series arrangements - any may be operated wet so as to avoid the re-entrainment of particles from the inside walls of the devices. The cyclone's principle of operation involves the migration of particles suspended in the gas stream, under the influence of centrifugal force, across the diameter of the device and toward the wall for collection, as the gas stream simultaneously spirals downward. As a result, the collection efficiency obtained with a cyclone is dependent on its diameter and height. Since cyclones, when used as control equipment, only collect the larger particles and seldom attain extremely high efficiencies, the amount of particulate matter that is removed from the hopper is a good indicator of the amount that may be emitted to the atmosphere.

The emission control equipment inspection form also includes provisions for the description of any other type of control equipment that may be encountered by the field investigator. For such equipment, the inspector should record the type or name of the device involved, its mode of operation (for example, centrifugal, diffusive, electrostatic, gravitational, etc.), and its geometric form and dimensions relevant to the flow of the gas and the performance of the device.

A generally applicable emission source summary form (which can also be filled out by environmental regulatory personnel or by a source facility representative prior to or subsequent to the inspection visit) is presented as Exhibit 8-11. The form is chemical-substance emission oriented; each material of concern is to be listed in the first column, the equipment related to the substance is to be listed in the second column (along with any pertinent instrumentation readings, such as temperatures, pressures, volumes and flow rates, as discussed previously), and emission parameter information (where known, or when subsequently calculated) is to be listed in the remaining columns. A minimum of proprietary information need be sought in completing the form, since emission data are by law not entitled to confidential status.

A self-explanatory toxic emission preliminary assessment procedure that may be used by the inspector is outlined as Exhibit 8-12. Alternatively, after having completed his inspection visit and returned to his office, the field investigator can utilize the information he has gathered in estimating the uncontrolled emission rates and the efficiencies of air pollution control devices in reducing potentially toxic emissions (under both normal and abnormal operating conditions), approximating the ground-level ambient air concentrations of the toxic substances (in consultation with agency personnel responsible for atmospheric dispersion modeling, or employing appropriate references to obtain dilution factors (6) and/or

volumes (15)), and comparing the concentrations to permissible ambient levels determined as discussed previously in this manual, or by other means. The principal reference documents that are recommended for use by toxic air pollutant emission field investigators are listed in Exhibit 8-13. Finally, the field investigator should prepare a report for his supervisor including his observations and describing his findings. Since there are relatively few toxic substance emission standards, such inspection reports should be made available to those involved in the development of such regulations.

EXHIBIT 8-1

ITEMS OF SAFETY AND INSPECTION EQUIPMENT

Safety Equipment

Hard hat

Safety eyeglasses or goggles

Chemical-resistant safety shoes or boots

Gas mask with activated carbon canisters (or other suitable safety respirator)

Ear protectors (e.g., cotton or synthetic plugs)

Protective gloves

Fireproof clothing

Any other items required of visitors by the plant owner or operator

Inspection Equipment

Credentials to establish identity and authority

Inspection manual and forms

Notebook and writing implements

Wristwatch with sweep-second hand (or wristwatch and stopwatch)

Camera with film

Tape measure

Flashlight

Magnetic compass

Sample bags (with ties) or containers, with pocket knife (or scraper) and sample brush

EXHIBIT 8-2
PRE-ENTRY CHEMICAL EMISSION SOURCE INSPECTION FORM

Facility name _____
 Facility address _____
 Person to contact _____ Telephone no. _____
 Inspector _____ Date _____ Time _____ ☐ am ☐ pm
 Reason for insp: ☒ Routine (Last insp. date: _____) ☐ Other _____
 Temperature _____ Of Wind speed _____ mph Wind direction _____
 Cloud cover _____ Precipitation _____ Other observ. _____

VISIBLE EMISSIONS

Exhaust Type	Release Location	Plume Opacity (%)	Plume Color	Back- ground Descrip.	Obser- ver's Location	Dist.(ft) & Dir. to Plume	Photo No.
Stacks							

Vents

Fugitive

Undeter-
mined

ODOROUS EMISSIONS

Odor Type	Odor Strength	Odor Persis- tence	Observer's Location	Apparent Release Location	Dist. (ft) & Dir. to Source	Photo No.

PARTICULATE DEPOSITION

Recep. Type	Recep. Loc.	Dust Color	Dust Coverage	Photo No.	Sample No.

ECOLOGICAL EFFECTS

Recep. Type	Recep. Loc.	Effect Description	Photo No.	Sample No.

SKETCH OF FACILITY LOCATION

(With emission source locations, property lines and fences, entrance gates, surrounding roads, homes and institutions, parks and forests, lakes and streams, observation and receptor locations listed above, distances and compass directions, etc. - use reverse if more space is required.)

EXHIBIT 8-3
REACTOR INSPECTION FORM

Facility name and address _____
Inspector _____ Inspection date _____
Name of system _____

EQUIPMENT DESCRIPTION

Name of reactor _____ Loc./desig. on plant layout _____ Photo no. _____
Capacity _____ gal Diam _____ ft Ht. or length _____ ft Condition _____
TYPE: ☐ Batch ☐ Continuous ☐ Other _____
AUX. EQUIP.: ☐ Column ☐ Ejector ☐ Condenser ☐ Scrubber
 ☐ Afterburner ☐ Other _____
CHARGING: ☐ Port ☐ Pipe ☐ Other _____
AGITATION: ☐ Yes ☐ No HEATING: ☐ Yes ☐ No COOLING: ☐ Yes ☐ No
PRESSURIZATION: ☐ Yes ☐ No VACUUM: ☐ Yes ☐ No
Processing Time _____ Temperature cycle _____ Pressure cycle _____
 min _____ of _____ min _____ psig min
Discharging method _____ Cleaning method _____

MATERIALS PRESENT

Materials & Wts.(#) Intermediates Products & Wts.(#) By-Products

EXHAUST GAS

Release loc. or desig. Release ht. Plume opacity Odor Photo
on plant layout _____ ft _____ % no.
Vol. flow rate _____ acfm Vent diam. _____ in Exit vel. _____ fps Exit temp _____ °F
Valve pressure setting & _____ Rupture disc pressure rating &
condition _____ psig condition _____ psig
Monitor. equip. rdgs. & units _____ Blowdown & spill controls _____

SKETCH

(Use reverse if more space is required)

8-24

EXHIBIT 8-4
DRYER INSPECTION FORM

Facility name and address _____
Inspector _____ Inspection date _____
Name of system _____

EQUIPMENT DESCRIPTION

Name of equip. _____ Loc./desig. on plant layout _____ Photo no. _____
TYPE: ☐ Agitated ☐ Fluid bed ☐ Gravity ☐ Pneumatic conveying
☐ Rotary ☐ Screen ☐ Screw conveyor ☐ Spray ☐ Tray
☐ Other _____
OPERATION: ☐ Batch ☐ Continuous ☐ Other _____
HEAT TRANSFER: ☐ Direct ☐ Indirect _____
DRYING MEDIUM: ☐ Air ☐ Other gas _____
Capacity _____ Temp. cycle _____ Pressure cycle _____ Condition _____
lb _____ °F min _____ mm Hg min _____
☐ in ☐ out _____

MATERIALS PRESENT

Materials to be Dried	Physical Form	Mesh Size (x)	Moisture In (%)	Moisture Out (%)
--------------------------	------------------	--------------------	----------------------	-----------------------

CONTROL EQUIPMENT

☐ Cyclone ☐ Filter ☐ Scrubber ☐ Afterburner ☐ Adsorber
☐ Condenser ☐ Other _____

EXHAUST GAS

Release loc. or desig. on plant layout _____ Release ht. _____ ft _____ Plume opacity _____ % _____ Odor _____ Photo no. _____
Vol. flow rate _____ acfm Vent diam. _____ in Exit vel. _____ fps Exit temp _____ °F
Monitoring equip. rdgs. & units _____

SKETCH

(use reverse if more space is required)

EXHIBIT 8-5
GRINDING OR MILLING OPERATION INSPECTION FORM

Facility name and address _____
Inspector _____ Inspection date _____
Name of system _____

EQUIPMENT DESCRIPTION

Capacity _____ lb Condition _____
TYPE: ☐ Ball ☐ Hammer ☐ Jet ☐ Pebble ☐ Planetary ☐ Ring-roller
☐ Rod ☐ Roller ☐ Tube ☐ Vibratory ☐ Other _____
OPERATION: ☐ Batch ☐ Continuous ☐ Other _____

MATERIAL PRESENT

Material to be ground or milled _____
Physical form before process _____
Material size before process _____ x _____ mesh
Physical form after process _____
Material size after process _____ x _____ mesh

CONTROL EQUIPMENT

☐ Cyclone ☐ Filter ☐ Scrubber ☐ Other _____

EXHAUST GAS

Release loc. or desig. Release ht. Plume opacity Odor Photo
on plant layout _____ ft _____ % _____ no.
Vol. flow rate _____ acfm Vent diam. _____ in Exit vel. _____ fps Exit temp _____ °F
Monitoring equip. rdgs. & units _____

SKETCH

(Use reverse if more space is required)

8-26

EXHIBIT 8-6
STORAGE TANK INSPECTION FORM

Facility name and address
Inspector

		Inspection date	
Loc./ desig. on Plant Layout	Material Stored	Storage Temp. (°F)	Capacity (gal)
		Annual Thru- put (gal/ yr)	Diameter (ft)
		Height (ft)	Roof (ft)
		Level Indicator	Shell Condition
		Paint and Gnrl.	Exposure to Sun, Wind
			Pressure (psig)
			Control Equipment
			No.

Facility name and address _____
 Inspector _____ Inspection date _____
 Location or designation on plant layout _____ Photo no. _____
 Name of system _____
 Name of equipment _____
 Number of similar items of equipment described on this form _____

Material handled	Flow rate	☐ gpm ☐ lb/min
------------------	-----------	---

Outlet temp. _____ °F Outlet pressure _____ psia

Seal condition	Leakage
Good	0.00
Fair	0.01
Poor	0.02
Very poor	0.03
Seal failed	0.04

Emission control

8-28

EXHIBIT 8-8
HOOD AND DUCTWORK INSPECTION FORM

Facility name and address _____
Inspector _____ Inspection date _____
Location or designation on plant layout _____ Photo no. _____
Name of system _____
Name of source equipment controlled _____

Volumetric ventilation rate _____ acfm at _____ °F

Hood type: ☐ Plain rectangular ☐ Flanged rectangular
☐ Plain slot ☐ Flanged slot
☐ Plain circular ☐ Flanged circular
☐ Booth ☐ Other _____

Hood dimensions: Length _____ in. Width _____ in. Height _____ in.
Diam. _____ in. Flange _____ in. Distance to source _____ in.

Air flow distribution aids: ☐ Multiple take-offs (No. _____)
☐ Baffles ☐ Filter banks ☐ Other _____ ☐ None _____

Source release velocity: ☐ High ☐ Moderate ☐ Low ☐ Negligible

Interfering air currents: ☐ High ☐ Moderate ☐ Low ☐ Negligible

Ductwork operation: ☐ Negative pressure ☐ Positive pressure

Hood condition _____ Ductwork condition _____
Connections _____

SKETCH
(use reverse if more space is required)

EXHIBIT 8-9
INDUSTRIAL WASTE INCINERATOR INSPECTION FORM

Facility name and address _____
Inspector _____ Inspection date _____
Name of system _____

EQUIPMENT DESCRIPTION

Name of equip. _____ Loc./desig. on plant layout _____ Photo no. _____
Operation: ☐Batch ☐Continuous ☐Other _____
No. of chambers _____ Volumes of chambers _____ ft³
Waste preparation & charging method _____ Charging rate _____ lb/hr
Aux. Fuel: ☐Oil _____ gph ☐Gas _____ scfh ☐None ☐Other & rate _____
Draft: ☐Forced ☐Induced ☐Natural ☐Preheated ☐Other _____
Operating temperature _____ °F Temp. controls _____
Equipment condition _____

<u>Material</u>	<u>WASTE COMPOSITION</u> <u>Physical Form</u>	<u>Percent by Wgt.</u>
-----------------	--	------------------------

CONTROL EQUIPMENT

☐Afterburner ☐Scrubber ☐Other _____

EXHAUST GAS

Release loc. or desig. on plant layout _____ Release ht. _____ ft Plume opacity _____ % Odor _____ no. Photo _____
Vol. flow rate _____ acfm Vent diam. _____ in Exit vel. _____ fps Exit temp. _____ °F
Monitoring equipment readings & units _____

SKETCH
(use reverse if more space is required)

8-30

EXHIBIT 8-10
EMISSION CONTROL EQUIPMENT INSPECTION FORM

Facility name and address _____
Inspector _____ Inspection date _____
Location or designation on plant layout _____ Photo no. _____
Name of system _____
Name of source equipment controlled _____

Gas volumetric flow rate _____ acfm (☐ in ☐ out)
Entrance temp. _____ °F Exit temp. _____ °F Pressure drop _____ "H₂O

Check all types utilized to control the source equipment:

☐ Condenser TYPE: ☐ Shell-and-tube ☐ Barometric ☐ Other _____
Condition _____
Cooling fluid _____ Coolant flow rate _____ gpm
Coolant inlet temperature _____ °F
Coolant outlet temperature _____ °F
Heat transfer area _____ ft²

☐ Scrubber TYPE: ☐ Spray ☐ Packed ☐ Venturi ☐ Ejector ☐ Other _____
Condition _____
Scrubbing liquid composition and pH _____
Scrubbant circulation rate _____ gpm
Geometric form _____ Dimensions _____ in.

☐ After-burner TYPE: ☐ Direct-flame ☐ Catalytic ☐ Heat recovery
☐ Other _____ Condition _____
Dimensions: _____ in. diam _____ in. long Temp. _____ °F

☐ Adsorber TYPE: ☐ Activated Carbon ☐ Other _____
Condition _____
No. of beds _____ Weight of adsorbate in each _____ lb
Time on-line before regeneration _____ min.
REGENERATION: ☐ Steam ☐ Condensation ☐ Incineration
☐ Replacement ☐ Other _____

☐ Filter TYPE: ☐ Shaker ☐ Reverse-air ☐ Panel ☐ Other _____
Condition _____
Filter material _____
Filter surface area _____ ft²
Disposition of dust _____

☐ Cyclone TYPE: ☐ Simple ☐ Multiple ☐ Series ☐ Wet ☐ Other _____
Condition _____ No. of clones _____
Diam. of each _____ in. Hgt. of each _____ in.
Disposition of dust _____

☐ Other Type or name _____
Mode of operation _____
Condition _____
Geometric form _____ Dimensions _____ in.

SKETCH
(use reverse if more space is required)

EXHIBIT 8-11

Sheet of _____
Completed by _____
Date completed _____

Facility name

Telephone no.

[illegible]

Emission Parameters for Substance		
Average	Maximum ^c	Basis of
mg/m ³	lb/yr	mg/m ³ lb/yr
		Estimated

NOTES:

- a. This refers to any substance other than air or water which at the conditions present has a vapor pressure of 1mm Hg or more, or is present to any extent as particles with dimensions of 1mm or less, may follow a direct or indirect path leading to the ambient air, and may then result in toxic effects.
- b. Items of equipment should be shown on a plant layout or plot plan, which should be attached to this sheet; equipment identification codes may be defined on this sheet and placed on the layout or plan.
- c. Maximum emission concentrations are rates that occur due to normal operating condition fluctuations, start-up and shut-down procedures, and malfunctions and breakdowns that can be reasonably expected to occur during the plant lifetime; all such maxima should be listed and their causes designated.
- d. Emission estimate basis may be test result, vapor pressure calculation, material balance, etc.

EXHIBIT 8-12
TOXIC EMISSION PRELIMINARY ASSESSMENT PROCEDURE

1. What chemical substance is present that could be released?
 - a. Particulate less than 1 mm in size _____
 - b. Material with vapor pressure of at least 1 mm Hg _____
2. What are the source emissions prior to entering any control devices?
 - a. Concentration from vapor pressure or chemical equilibrium data, etc.:
Average _____ mg/m^3 _____ mg/m^3
ppm Maximum _____ ppm
3. What is the expected emission control efficiency?
Average emission conditions _____ %
Maximum emission conditions _____ %
4. What are the emissions leaving the control devices?
 - a. Concentration: Average _____ mg/m^3 _____ mg/m^3
ppm Max. _____ ppm
 - b. Release rate: Average _____ lb/hr Max. _____ lb/hr
5. What is the expected peak ambient concentration?
 - a. From concentration dilution factor =
 $3 (3.16 + \text{Dist. to Boundary or Recep.}/10 \text{ Vent Diam.})^2$
Average _____ mg/m^3 _____ mg/m^3
ppm Maximum _____ ppm
 - b. From release rate dilution volume =
 $3.14 (\text{Wind speed}) (\text{Release height})^2$
Average _____ mg/m^3 _____ mg/m^3
ppm Maximum _____ ppm
 - c. From odor thresholds and perceptions
Average _____ mg/m^3 _____ mg/m^3
ppm Maximum _____ ppm
6. What is the permissible ambient concentration?
 - a. Ambient standard, guideline or criterion
Average _____ mg/m^3 _____ mg/m^3
ppm Maximum _____ ppm for _____ hr.
 - b. Calculated from 1.65×10^{-3} (TLV) _____ mg/m^3
ppm
 - c. Calculated from 4.77×10^{-5} (LD₅₀ in mg/kg body wgt.) _____
 - d. Carcinogen recommended limit: 1 ng/m³ or 0.000001 mg/m³
7. What is the potential for a toxic air pollution problem, based on a comparison of the answers to Questions 5 and 6?

EXHIBIT 8-13

PRINCIPAL REFERENCE DOCUMENTS RECOMMENDED FOR USE BY
TOXIC AIR POLLUTANT EMISSION INVESTIGATORS

<u>Title</u>	<u>Author</u>	<u>Subject</u>	<u>Reference No.</u>
Toxic Substances List (NIOSH)	Christensen et al	LD ₅₀ 's, TLV's, trade names	(2)
Dangerous Proper- ties of Industrial Materials	Sax	Toxicity rat- ings, LD ₅₀ 's, TLV's, etc.	(3)
Handbook of Chem- istry and Physics (CRC)	Weast	Chemical formu- lae, physical properties	(4)
Chemical Engi- neers' Handbook	Perry and Chilton	Chemical pro- cesses, equip- ment, etc.	(9)
Air Pollution Engineering Manual (AP-40)	Danielson	Control methods, equipment, emis- sion factors, etc.	(13)
Industrial Venti- lation	ACGIH	Hood design, TLV's, etc.	(14)
Workbook of Atmos- pheric Dispersion Estimates (AP-26)	Turner	Calculating am- bient exposures	(15)

REFERENCES

1. U.S. Dept. of Labor, Occupational Safety and Health Administration, General Industry Safety and Health Standards, OSHA 2206 (29 CFR 1910), January 1976.
2. Christensen, H.E., ed., Luginbyhl, T.T., ed. and Carroll, B.S., asst. ed., Toxic Substances List, HEW Publication No. (NIOSH) 74-134, Rockville, MD, June 1974.
3. Sax, N.I., Dangerous Properties of Industrial Materials, 4th ed., Van Nostrand Reinhold Co., New York, 1975.
4. Weast, R.C., ed., Handbook of Chemistry and Physics, 45th ed., Chemical Rubber Co., Cleveland, 1964.
5. Handy, R. and Schindler, A., Estimation of Permissible Concentrations of Pollutants for Continuous Exposure, Publication No. EPA-600/2-76-155, June 1976.
6. Phelps, A.H., "Odors," Chapter 8 in Stern, A.C., ed., Air Pollution, Vol. 3, 3rd ed., Academic Press, New York, 1976.
7. Leonardos, G., "The Profile Approach to Odor Measurement" in Proceedings: Mid-Atlantic States Section, APCA Semi-annual Technical Conference on Odors: Their Detection, Measurement and Control, New Brunswick, NJ, May 1970, Air Pollution Control Association, Pittsburgh.
8. Summer, W., Odor Pollution of Air, CRC (Chemical Rubber Co.) Press, Cleveland, 1971.
9. Perry, R.H., and Chilton, C.H., editors, Chemical Engineers' Handbook, 5th ed., McGraw-Hill, New York, 1973.

10. U.S. EPA, Compilation of Air Pollutant Emission Factors, 2nd ed., Publication No. AP-42, February 1976.
11. U.S. DHEW, Control Techniques for Hydrocarbon and Organic Solvent Emission from Stationary Sources, NAPCA Publication No. AP-68, March 1970.
12. U.S. EPA, Control Techniques for Particulate Air Pollutants, Publication No. AP-51, December 1972.
13. Danielson, J.A., ed., Air Pollution Engineering Manual, 2nd ed., EPA Publication No. AP-40, May 1973.
14. American Conference of Governmental Industrial Hygienists, Industrial Ventilation, 11th ed., Committee on Industrial Ventilation, Lansing, MI, 1970.
15. Turner, D.B., Workbook of Atmospheric Dispersion Estimates, EPA Publication No. AP-26, March 1972.